U. S. DEPARTMENT OF COMMERCE

BUILDING MATERIALS AND STRUCTURES

REPORT BMS67

Structural Properties of "Mu-Steel" Prefabricated Sheet-Steel Constructions for Walls, Partitions, Floors, and Roofs Sponsored by Herman A. Mugler

by

HERBERT L. WHITTEMORE,
AMBROSE H. STANG, *and*
VINCENT B. PHELAN

NATIONAL
BUREAU OF STANDARDS

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The Forest Products Laboratory of the Forest Service is cooperating with both committees on investigations of wood constructions.

[For list of BMS publications and directions for purchasing, see cover page III.]

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BUILDING MATERIALS *and* STRUCTURES

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by HERBERT L. WHITTEMORE, AMBROSE H. STANG, *and* VINCENT B. PHELAN

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The National Bureau of Standards is a fact-finding organization; it does not "approve" any particular material or method of construction. The technical findings in this series of reports are to be construed accordingly.

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Foreword

This report is one of a series issued by the National Bureau of Standards on the structural properties of constructions intended for low-cost houses and apartments. These constructions were sponsored by organizations within the building industry advocating and promoting their use. The sponsor built and submitted the specimens described in this report for participation in the program outlined in BMS2, Methods of Determining the Structural Properties of Low-Cost House Constructions. The sponsor, therefore, is responsible for the design of the constructions and for the description of the materials and methods of fabrication. The Bureau is responsible for the testing of the specimens and the preparation of the report.

This report covers only the load-deformation relations and strength of the structural element submitted when subjected to compressive, transverse, impact, concentrated, and racking loads by standardized methods simulating the loads to which the element would be subjected in actual service.

The National Bureau of Standards does not "approve" a construction, nor does it express an opinion as to its merits for reasons given in reports BMS1 and BMS2. The technical facts presented in this series provide the basic data from which architects and engineers can determine whether a construction meets desired performance requirements.

Lyman J. Briggs, *Director.*

Structural Properties of "Mu-Steel" Prefabricated Sheet-Steel Constructions for Walls, Partitions, Floors, and Roofs Sponsored by Herman A. Mugler

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ABSTRACT

For the program on the determination of the structural properties of low-cost house constructions, Herman A. Mugler submitted 33 specimens representing his "Mu-Steel" prefabricated sheet-steel wall, partition, floor, and roof constructions.

The wall specimens were subjected to compressive, transverse, impact, concentrated, and racking loads; the partition specimens to impact and concentrated loads; the floor specimens to transverse, impact, and concentrated loads; and the roof specimens to transverse and concentrated loads. The transverse, impact, and concentrated loads were applied to both faces of the wall specimens. The impact and concentrated loads were applied to both faces of the partition specimens. The loads simulated the loads to which the elements are subjected in actual service.

The deformations under load and the sets after the load was removed were measured for uniform increments of load. The results of the measurements are presented in graphs and tables.

I. INTRODUCTION

To provide technical facts on the performance of constructions for low-cost houses, to discover promising new constructions, and ultimately to determine the properties neces-

sary for acceptable performance in actual service, the National Bureau of Standards has invited the cooperation of the building industry in a program of research on building materials and structures suitable for low-cost houses and apartments. The objectives of this program are described in BMS1, Research on Building Materials and Structures for Use in Low-Cost Housing.

To determine the strength of house constructions in the laboratory, standardized methods were developed for applying loads to portions of a completed house. Included in this study were masonry and wood constructions of types which have been extensively used in this country for houses and whose behavior under widely different service conditions is well known to builders and the public. The reports on these constructions are BMS5, Structural Properties of Six Masonry Wall Constructions, and BMS25, Structural Properties of Conventional Wood-Frame Constructions for Walls, Partitions, Floors, and Roofs. The masonry specimens were built by the Masonry Construction Section of this Bureau, and the wood-frame specimens were built and tested by the Forest Products Laboratory at Madison, Wis.

The present report describes the structural properties of four elements of a house sponsored by one of the manufacturers in the building industry. The wall specimens were subjected to compressive, transverse, impact, concentrated, and racking loads, simulating the loads to which the walls of a house are subjected. In actual service compressive loads on a wall are produced by the weight of the roof, second floor and second-story walls, if any, by furniture and occupants, and by snow and wind loads on the roof. Transverse loads on a wall are produced by wind, concentrated and impact loads by accidental contact with heavy objects, and racking loads by the action of the wind on the adjoining walls. For non-loadbearing partitions, impact loads may be applied accidentally by furniture or persons falling against the partition, and concentrated loads by furniture, a ladder, or other object leaning against the partition. Transverse loads are applied to floors by furniture and occupants; concentrated loads by furniture, for example the legs of a piano; and impact loads by objects falling on the floor or by persons jumping on the floor. Transverse loads are applied to roofs by wind and snow; concentrated loads by persons walking on the roof, and by tools and equipment when the roof is constructed and repaired.

The deflection and set under each increment of load were measured because the suitability of a construction depends not only on its resistance to deformation when loads are applied, but also on its ability to return to its original size and shape when the loads are removed.

II. SPONSOR AND PRODUCT

The specimens were submitted by Herman A. Mugler, Lynbrook, N. Y., and represented prefabricated wall, partition, floor, and roof constructions marketed under the trade name "Mu-Steel." These constructions consisted of channel-shaped panels of sheet steel fastened together by bolts.

III. SPECIMENS AND TESTS

The specimens represented four elements of a house and were assigned the following symbols: wall, *CU;* partition, *CV;* floor, *CW;* roof, *CX*. The individual specimens were assigned the designations given in table 1.

TABLE 1.—*Specimen designations, wall CU, partition CV, floor CW, and roof CX*

Element	Specimen designation	Load	Load applied
Wall	*C1, C2, C3*	Compressive	Upper end.
Do	*T1, T2, T3*	Transverse	Inside face.
Do	*T4, T5, T6*	do	Outside face.
Do	*I1, I2, I3*	Impact [a]	Inside face.
Do	*I4, I5, I6*	do	Outside face.
Do	*P1, P2, P3*	Concentrated	Inside face.
Do	*P4, P5, P6*	do	Outside face.
Do	*R1, R2, R3*	Racking	Near upper end.
Partition	*I1, I2, I3*	Impact [a]	"Inside" face.[b]
Do	*I4, I5, I6*	do	"Outside" face.[b]
Do	*P1, P2, P3*	Concentrated	"Inside" face.
Do	*P4, P5, P6*	do	"Outside" face.
Floor	*T1, T2, T3*	Transverse	Upper face.
Do	*I1, I2, I3*	Impact [a]	Do.
Do	*P1, P2, P3*	Concentrated	Do.
Roof	*T1, T2, T3*	Transverse [c]	Do.
Do	*P1, P2, P3*	Concentrated	Do.

[a] The impact and the concentrated loads were applied to the same specimens, the impact loads first.
[b] The quoted "inside" and "outside" faces refer to partition specimens only.
[c] The transverse and the concentrated loads were applied to the same specimens, the transverse loads first.

Except as mentioned below, the specimens were tested in accordance with BMS2, which report also gives the requirements for the specimens and describes the presentation of the results of the tests, particularly the load-deformation graphs.

Because, under compressive load, there may be considerable shortening at the bolted connections between the panels and the sill and the cap, the shortening of the entire specimen may not be proportional to the value obtained from the compressometers attached to the specimen over only a portion of its entire height. Therefore, the shortenings and the sets were measured with compressometers attached to the steel plates through which the load was applied, not attached to the specimen as described in BMS2.

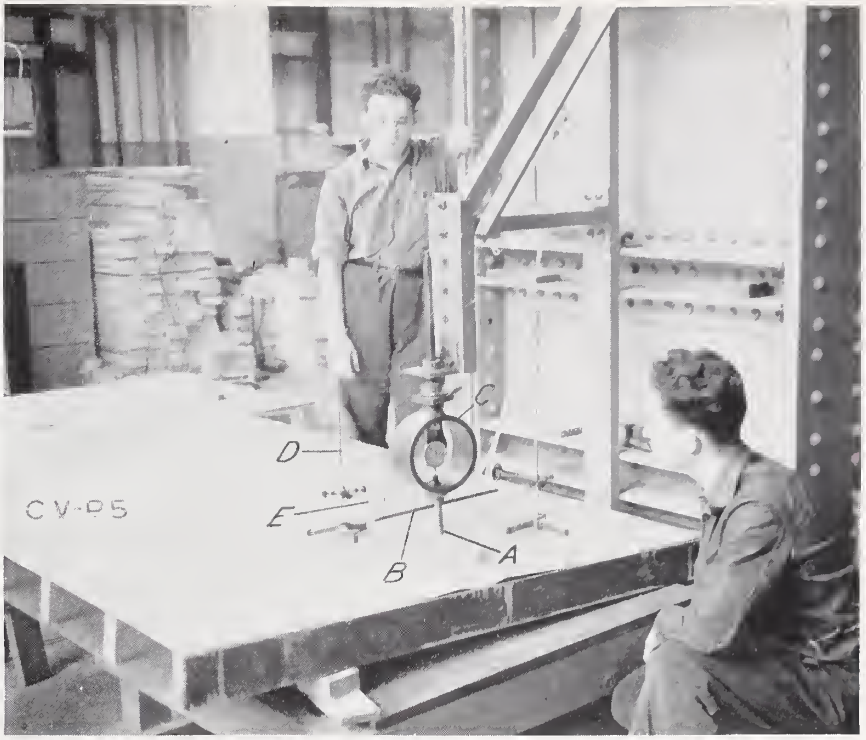

Figure 1.—*Concentrated load on partition specimen CV–P5.*

A, disk; *B*, crossbar; *C*, ring dynamometer; *D*, stand; *E*, dial micrometer.

The lateral deflections under compressive loads were measured with a deflectometer of fixed gage length, which consisted of a light (duralumin) tubular frame having a leg at one end and a hinged plate at the other. The deflectometer was attached in a vertical position by clamping the hinged plate to one of the faces of the specimen near the top. The gage length (distance between the points of support) was 7 ft. 6 in. A dial micrometer was mounted on the frame at midlength, with the spindle in contact with the wall specimen. The dial was graduated to 0.001 in. and the readings were recorded to the nearest division. There were two deflectometers on the specimen, one near each outer stud (i. e., the two flanges of adjacent channels). This method of measurement was used instead of the taut-wire mirror-scale method described in BMS2.

The indentation under concentrated load and the set after the load was removed were measured, not the set only as described in BMS2. The apparatus is shown in figure 1.

The load was applied to the steel disk, *A*, to which the crossbar, *B*, was rigidly attached. The load was measured by means of the ring dynamometer, *C*. Two stands, *D*, rested on the face of the specimen, each supporting a dial micrometer, *E*, the spindle of which was in contact with the crossbar 8 in. from the center of the disk. The micrometers were graduated to 0.001 in. and readings were recorded to the nearest division. The initial reading (average of the micrometer readings) was observed under the initial load, which included the weight of the disk and dynamometer. A load was applied to the disk, and the average of these micrometer readings minus the initial reading was taken as the depth of the indentation under load.

The deformations under racking load were measured with a right-angle deformeter, consisting of a steel channel and a steel angle braced to form a rigid connection. The channel of the deformeter was fastened along the top of the specimen by self-tapping screws with the steel angle extending downward in the plane of the specimen. To the stop, which prevented motion of the specimen horizontally, a dial micrometer was attached with the spindle in contact with the steel angle of the deformeter. The gage length (distance from the top of the

specimen to the middle of the stop) was 8 ft. 2⅝ in. The micrometer was graduated to 0.001 in. and readings were recorded to the nearest division. The deformeter was used instead of the taut-wire mirror-scale deflectometer described in BMS2.

Because the partition specimens were unsymmetrical about a plane midway between the faces, six specimens were tested, not three as stated in BMS2.

The speed of the movable head of the testing machine was adjusted to 0.072 in./min for the compressive load on walls, 0.126 in./min for the transverse load on walls, 0.160 in./min for the transverse load on floors, and 0.211 in./min for the transverse load on roofs.

The tests were begun December 19, 1939 and completed January 29, 1940. The sponsor's representative witnessed the tests.

IV. MATERIALS

The information on the materials was obtained from the sponsor and from inspection of the specimens. The Forest Products Laboratory identified the species of the wood in the siding, subflooring, flooring, and spacer blocks. The Paper Section of this Bureau determined the physical properties of the insulating board. The Engineering Mechanics Section determined the moisture content of the wood.

1. Steel

Sheet.—Open-hearth, hot-rolled, annealed, pickled, black. The specified chemical composition of the steel is given in table 2. Specified tensile strength, minimum 40,000, maximum 50,000 lb/in^2. Bethlehem Steel Co.

TABLE 2.—*Specified chemical composition of the sheet steel*

Element	Content	
	Minimum	Maximum
	Percent	*Percent*
Carbon	0.08	0.11
Manganese	.30	.50
Phosphorus		.04
Silicon		.02
Copper	.12	

Structural.—Open-hearth, hot-rolled, annealed. Angles, 2- by 2- by ¼-in. Bethlehem Steel Co.

2. Bolts

Stove bolts.—Mild steel, ¼- in. diam, ½ in. long, round head (slotted), National Coarse (N. C.) threads 20 per inch, threaded full length, unfinished, bright. Nuts: mild steel, square, regular, $\frac{3}{16}$ in. thick, $\frac{7}{16}$ in. across flats, unfinished, bright. Corbin Screw Co.

3. Paint

The paint was ready-mixed aluminum paint. The formula for the paint was not furnished by the dealer. Marketing and Merchandising Corporation, "Tru Test, No. TT554."

4. Insulating Board

The insulating board, ½ in. thick, was made from wood fibers produced by a cold-grinding process. The fibers were chemically treated and intimately mixed with finely divided asphalt before felting into a board to provide greater resistance to water, rot, and termites. One surface of the boards had the appearance of a closely woven fabric designated "linen texture" and the other the appearance of a loosely woven fabric designated "burlap texture." Color, grayish brown. Insulite Co., "Graylite."

The physical properties of the insulating board are given in table 3. The samples of the board were taken from the specimens after they had been tested.

TABLE 3.—*Physical properties of insulating board, ½ in. thick*

[The samples were taken from the specimens after they had been tested]

Property	Value
Tensile strength:	
Machine direction ... lb/in.^{2}	303
Cross direction ... lb/in.^{2}	218
Transverse strength:[a]	
Machine direction ... lb	18
Cross direction ... lb	14
Deflection at rupture:	
Machine direction ... in	.60
Cross direction ... in	.67
Linear expansion for 45-percent change in relative humidity:	
Machine direction ... percent	.05
Cross direction ... percent	.10
Nail-holding strength:	
Machine direction ... lb	73
Cross direction ... lb	71
Density ... lb/ft^3	17.0
Moisture content, based on weight when dry ... percent	4
Air permeability ... $\frac{ft^3/hr}{ft^2\ (lb/in.^2)}$	593
Water absorption, by volume ... percent	4.9

[a] Span, 12 in.; width of specimens, 3 in.

The tensile strength, linear expansion, water absorption, and transverse strength and deflection at ultimate load were determined in accordance with Federal Specification LLL-F-321a, Fiber Board; Insulating. For these properties the insulating board complied with the requirements for class A.

The density, air permeability, and nail-holding strength were determined by the methods described in BMS13, Properties of Some Fiber Building Boards of Current Manufacture.

The moisture content was determined by drying in an oven at 212° F until the weight was constant.

5. Sheathing Paper

"Black Diamond."—Paper, impregnated with asphalt, one-ply; weight, 69 lb/500 ft²; width of roll, 3 ft 0 in. The Barrett Co., No. 14.

"Fords."—Paper, impregnated with asphalt, one-ply; weight, 55 lb/500 ft²; width of roll, 3 ft 0 in. The Ford Roofing Products Co.

6. Wood

Bevel Siding.—Identified as a yellow pine, probably *Pinus ponderosa*, No. 2 common, ¾ in. thick tapered to 5/16 in., 9½ in. wide, dressed.

Flooring, subflooring, and sheathing.—Identified as southern yellow pine, No. 2 common, 25/32 in. thick by 5¼ in. face width (nominal 1 by 6 in). S2S (surfaced two sides), tongued and grooved.

Spacer blocks.—Identified as cypress (*Taxodium distichum*), No. 1 common, S2S1E (surfaced two sides one edge), ¾- by 1⅝-in.

Moisture content.—The moisture content of the wood members in each structural specimen was determined by the use of an electric moisture meter. Readings were taken on each piece of bevel siding and three spacer blocks for each wall specimen; on three spacer blocks for each partition specimen; on four pieces of flooring, four pieces of subflooring, and three spacer blocks for each floor specimen; and on four pieces of sheathing and three spacer blocks for each roof specimen. To calibrate the moisture meter, moisture determinations were made on 18 pieces of siding, 12 pieces of flooring, 12 pieces of subflooring, and 15 pieces of spacer blocks by drying them to constant weight at 212° F. From these determinations the correction to be applied to the meter readings was found to be +0.3 for siding, +0.2 for subflooring, flooring, and sheathing, and +0.7 for spacer blocks. Values of the moisture content given in table 4, except as indicated by footnote *"b"*, were obtained by applying these corrections to the average of the meter readings and rounding the results to the nearest whole percent.

Table 4.—*Moisture content of wood*

[Determined on day the structural specimen was tested]

Wood	Construction symbol	Moisture content [a]		
		Minimum	Maximum	Average
		Percent	*Percent*	*Percent*
Bevel siding, yellow pine	*CU*	7	11	8
Subflooring, southern yellow pine	*CW*	7	18	11
Finish flooring, southern yellow pine	*CW*	7	21	11
Sheathing, southern yellow pine	*CX*	7	11	9
Spacer blocks, cypress	*CU*	8	8	8
	CV	8	13	11
	CW			[b] 6
	CX			[b] 5

[a] Based on the weight when dry.
[b] Determined by drying in an oven, because the values were below the range of the moisture meter.

7. Nails

Screw nails.

Heavy duty, steel, No. 5 Screw Gage (0.125-in. diam), 1½ in. long, quadruple thread, 7 threads per inch, flat head, diamond point, hardened, 250 nails per pound. Hillwood Manufacturing Co., "Helyx Drive Screw Nails."

Heavy duty, steel, No. 7 Screw Gage (0.151-in. diam), 1¾ in. long, quadruple thread, 7 threads per inch, flat head, diamond point, hardened, 148 nails per pound. Hillwood Manufacturing Co., "Helyx Drive Screw Nails."

Heavy duty, steel, No. 7 Screw Gage (0.151-in. diam), 2½ in. long, quadruple thread, 5 threads per inch, flat head, diamond point, hardened, 104 nails per pound. Hillwood Manufacturing Co., "Helyx Drive Screw Nails."

Finishing.—Steel wire, 8d, No. 12½ Stl. W. G. (0.0985-in. diam), 2½ in. long, bright, 189 nails per pound.

Roofing.—Steel wire, No. 10 Stl. W. G. (0.135-in. diam), 1 in. long, 7/16-in. diam flat head, bright, 215 nails per pound.

8. Roof Covering

Roll roofing.—Asphalt, smooth-surface; weight, 55 lb/108 ft^2; width of roll, 36 in. Continental Roofing Mills, "Battle Axe."

Roofing felt.—Asphalt-saturated; weight, 12 lb/108 ft^2; width of roll, 36 in. The Ford Roofing Products Co., "Fords."

Roof-coating.—Asphalt, containing finely ground asbestos fiber, diluted to a brushing consistency with a volatile solvent. Continental Roofing Mills, "Contico."

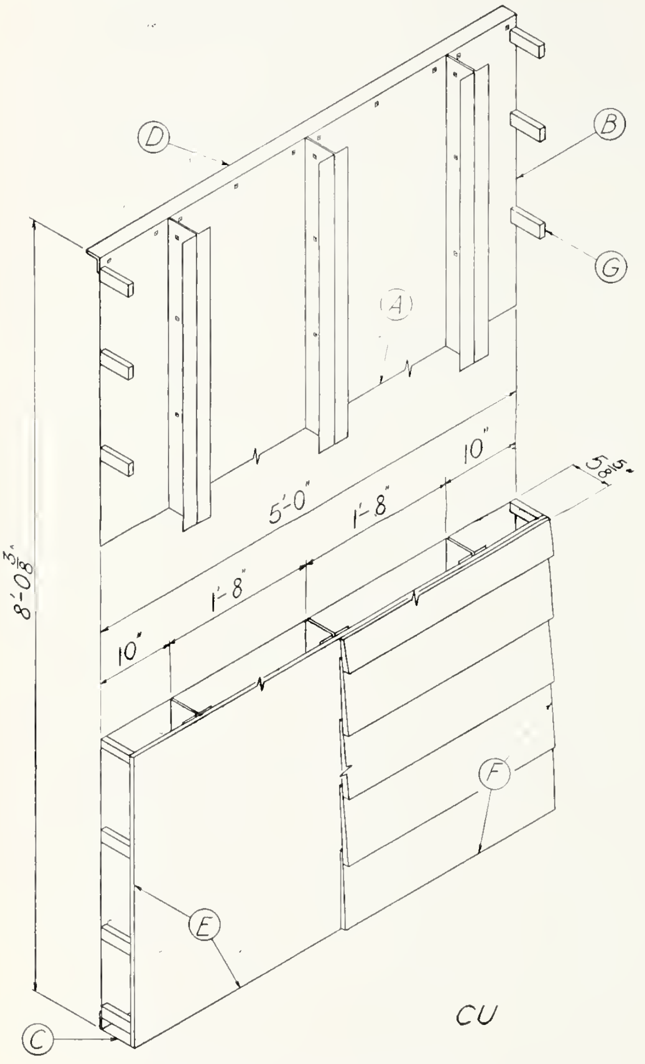

Figure 2.—*Four-foot wall specimen CU.*

A, full-width wall panels; *B*, half-width wall panels; *C*, angle sill; *D*, angle cap; *E* insulating board; *F*, bevel siding; *G*, spacer blocks.

V. WALL *CU*

1. Sponsor's Statement

Wall *CU* consisted of prefabricated sheet-steel channels fastened at the flanges; the webs were the inside face. The outside face was insulating board covered with bevel siding.

The price of this construction in Washington, D. C., as of July 1937, was \$0.43/ft^2.

(a) *Four-Foot Wall Specimens*

Each 4-ft wall specimen, shown in figure 2, was 8 ft 3/8 in. high, 5 ft 0 in. wide, and 5 5/8 in. thick and consisted of two full-width channel-shaped wall panels, *A*; two half-width panels, *B*; angle sill, *C*; angle cap, *D*; insulating board, *E*; bevel siding, *F*; and spacer blocks, *G*.

Wall panels.—The full-width wall panels, *A*, were sheet steel, No. 16 U. S. Std. Gage (0.0613 in. thick), 8 ft 1/8 in. high, 1 ft 8 in. wide, and 4 in. deep. The edges of the flanges were turned in 2 in., as shown in figure 3, for attaching the outside face and to increase the strength of the panel. Adjacent panels were fastened through the flanges by stove bolts 1/4-in. diam, 1/2 in. long. There were two rows of 9 bolts each spaced as shown in figure 4.

The half-width panels, *B*, were the same as a full-width panel cut along a longitudinal center line. There are no half-width panels in a house.

Sill.—The angle sill, *C*, sheet steel, No. 11 U. S. Std. Gage (0.1225 in. thick), was 4 1/8 by 2 in. by 5 ft 1/4 in. long. The sill was fastened to the panels by 10 stove bolts, 1/4-in. diam, 1/2 in. long, through the vertical (2-in.) leg and the webs of the panels. The spacing of the bolts is shown in figure 4.

Cap.—The angle cap, *D*, rolled structural steel, was 2 by 2 by 1/4 in., 5 ft 1/4 in. long. The cap was fastened to the panels in the same manner as the sill, by 10 stove bolts, 1/4-in. diam, 1/2 in. long, through the vertical leg of the cap and the webs of the panels. The spacing of the bolts is shown in figure 4.

Fabrication.—Adjacent panels were clamped together and the bolt holes were laid off with a rule and marked with a center punch. The

holes were drilled with a twist drill, ¼-in. diam, mounted in an electric hand drill.

The sill and the cap were then clamped to the wall panels and the bolt holes laid off. The difference between the nominal spacing and the actual spacing of the holes was as much as ¼ in. in some instances.

In a house all the panels are full width and there are no half-width panels. The middle bolt fastening the sill and the cap to the web of a panel is at midwidth of the panel. In the 4-ft wall specimens, therefore, there should have been a half-sized bolt (one-half the cross-sectional area of the full-sized bolt) at the edge of the specimen, fastening the sill and cap to each half-width panel. For convenience the bolts were full-sized (¼-in. diam) and, to provide an effective fastening, 1¼ in. from the edge of the specimen. It is believed that these changes had very little effect upon the structural properties of the wall specimens.

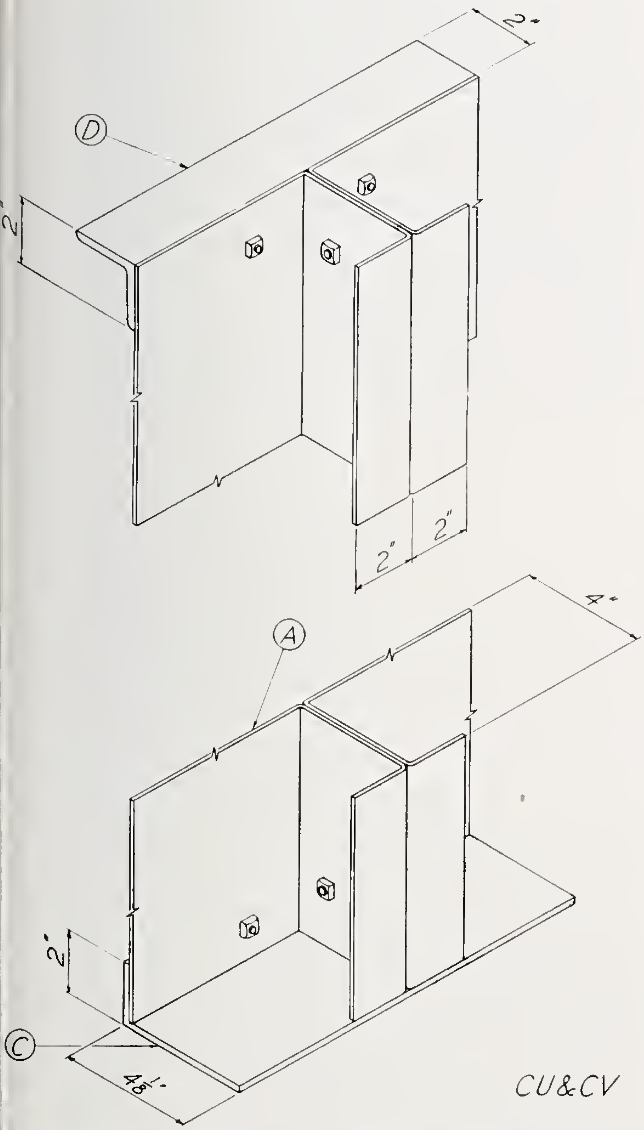

FIGURE 3.—*Detail of wall CU and partition CV.*
A, wall panels; *C*, angle sill; *D*, angle cap.

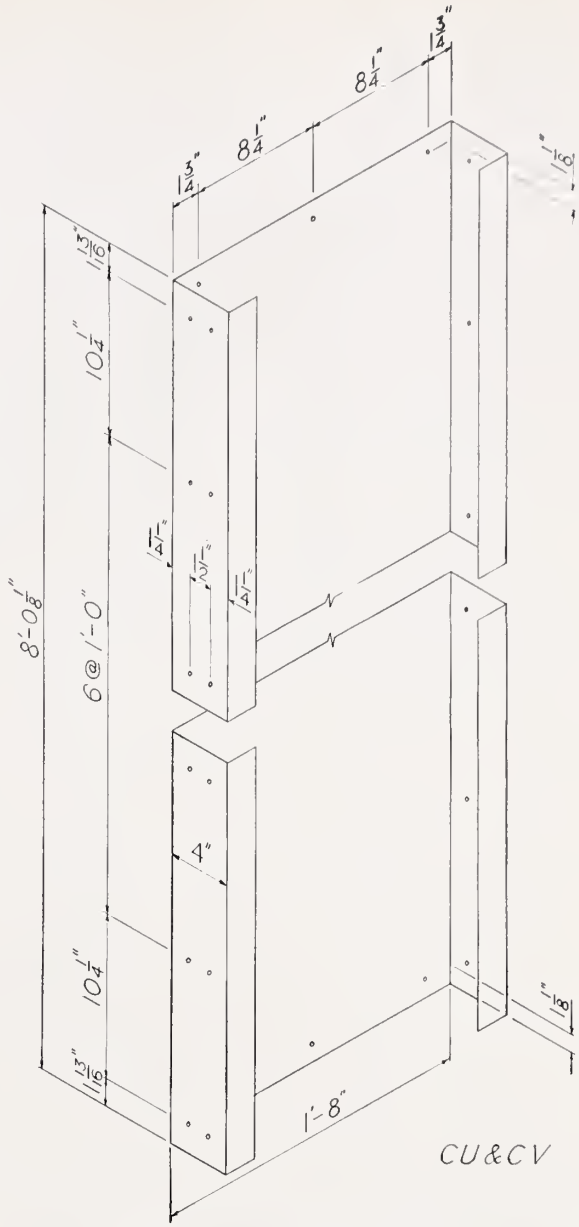

FIGURE 4.—*Bolt spacing for wall and partition panels.*

Paint.—Each panel, sill, and cap was covered with two coats of aluminum paint applied with

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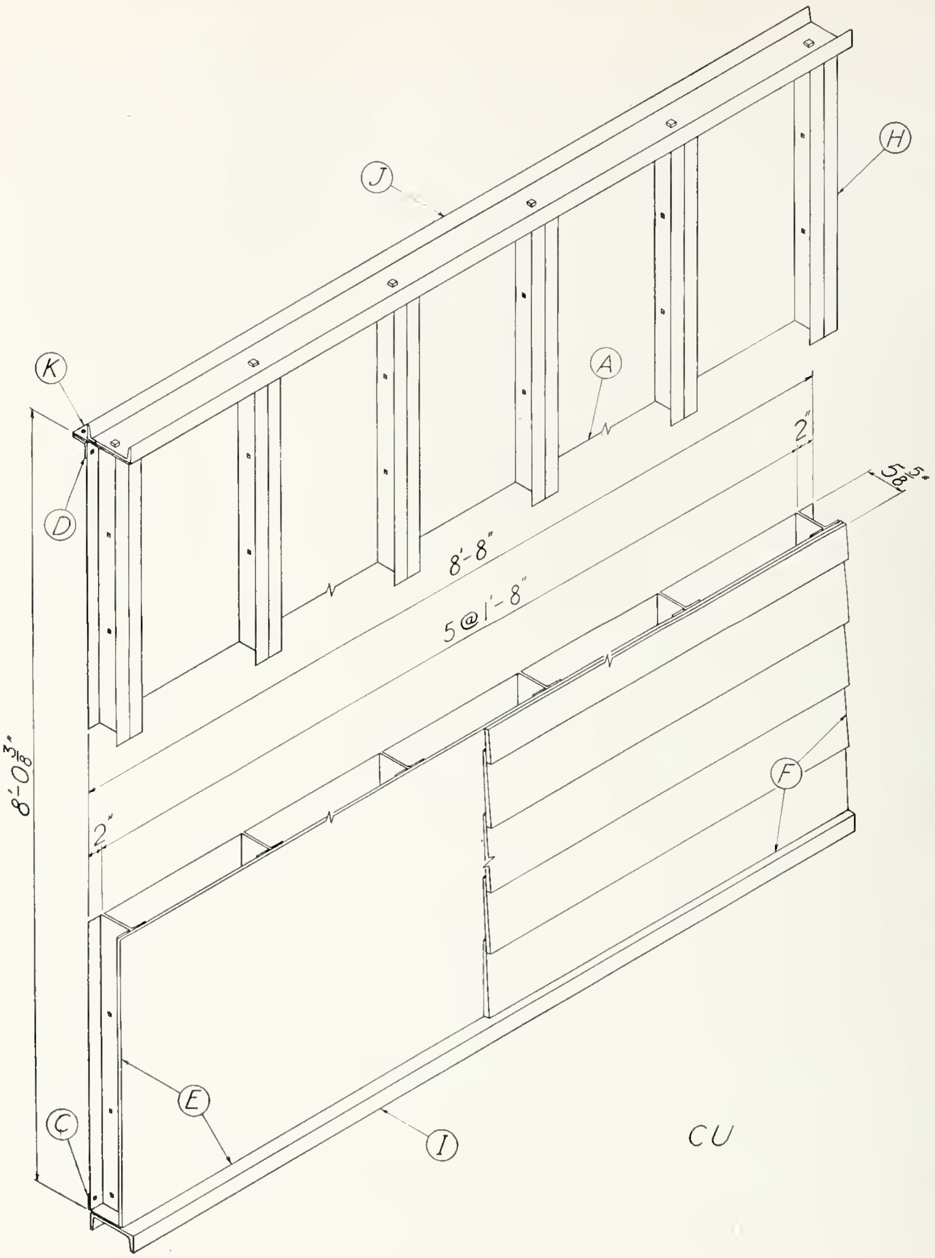


FIGURE 5.—*Eight-foot wall specimen CU.*

A, full-width wall panels; *C*, angle sill; *D*, angle cap; *E*, insulating board; *F*, bevel siding; *H*, special wall panel; *I* and *J*, structural-steel channels; *K*, sheet-steel strip.

a brush, one coat before assembling and one after.

Insulating board.—The insulating board, *E*, consisted of two pieces of "Graylite," 4 ft. 0 in. high, 5 ft. 0 in. wide, ½ in. thick, applied with the "burlap-texture" surface outward. There was one transverse joint, at midheight of the specimen, which was covered with a strip of sheathing paper 8 in. wide, 5 ft. 0 in. long. Both insulating board and sheathing paper were held in place by the bevel siding.

Bevel siding.—The bevel siding, *F*, was 12 pieces of yellow pine, ¾ in. thick, tapered to ⁵⁄₁₆ in., 9½ in. wide, 5 ft. 0 in. long, exposed 8 in. to the weather, fastened to the flanges of the panels by 1¾-in. screw nails. There were two nails through each piece of siding at each stud. One nail was near the upper edge through the siding, the insulating board, and through the flange of the stud. The other nail was near the lower edge through the two pieces of siding, the insulating board, and through the flange. The nails in adjacent pieces of siding were staggered with respect to the joint between the panels and close to it.

There was no paint on the bevel siding.

Blocks.—The spacer blocks, *G*, were cypress, ¾ by 1⅝ in., 4 in. long, nine blocks along each edge of the specimen, spaced 1 ft. Each block was fastened to the half-width panel by one 1¾-in. screw nail through the steel and into the block, and to the outside face by one 8d finishing nail through the siding and insulating board and into the block. There are no spacer blocks in a house.

FIGURE 6.—*Wall specimen CU–C1 under compressive load*

A, compressometer; *B*, deflectometer.

(*b*) *Eight-Foot Wall Specimens*

The 8-ft. wall specimens, shown in figure 5, were 8 ft. ⅜ in. high, 8 ft. 8 in. wide, and 5⅝ in. thick. They were similar to the 4-ft. specimens, except that there were five full-width panels. There were no half-width panels and no spacer blocks; but there was a special wall panel, *H*, having a face width of 2 in., at each edge of the specimen, to make the outer studs like the inner studs.

To apply the racking load uniformly along the width of the specimens, rolled structural-steel channels, *I* and *J*, were fastened to each specimen. The channel, *I*, 6 in. wide, weighing 10.5 lb./ft., was 8 ft. 8⅜ in. long and was fastened to the sill by six square-headed bolts, ½-in. diam., 1 in. long, spaced 1½ in. from each stud.

A sheet-steel strip, *K*, No. 16 U. S. Std. Gage (0.0613 in. thick), 8 in. wide and 8 ft. 8 in. long, was fastened to the angle cap by 17 stove bolts, ¼-in. diam., ½ in. long, one bolt adjacent to each bolt fastening the angle cap to the wall panels. The 6-in. channel, *J*, 10.5 lb./ft., was 8 ft. 8⅜ in. long and was fastened to the sheet-steel strip, *K*, by six bolts, ½-in. diam, 1 in. long, spaced 1½ in. from each stud. There are no channels or sheet-steel strips in a house.

The insulating board consisted of two pieces, 4 ft. 0 in. high, 8 ft. 8 in. wide. The horizontal joint at midheight was covered with a strip of sheathing paper 8 in. wide and 8 ft. 8 in. long. The bevel siding was 8 ft. 8 in. long. The insulating board and the bevel siding were fastened to the wall panels in the same way as in the 4-ft. specimens.

(*c*) *Comments*

Standard wall panels, all 1 ft. 8 in. wide, are available, having depths of 4, 6, and 8 in. and lengths up to 20 ft. Panels having other dimensions are special. To expedite the erection of the building, the holes for the bolts in the panels may be punched before the panels are shipped to the site.

In a house the angle sill for the wall is supported by the steel floor panels and bolted to them. At a corner, the flange of one wall panel is bolted to the web of the adjacent panel. At the bottom and top of openings for doors and windows, channels of sheet steel, No. 16 U. S. Std. Gage (0.0613 in. thick), are placed horizontally over the ends of wall panels. Conventional doors and windows, either wood or metal, may be used.

If the roof is flat, wall panels may be bolted horizontally to the roof panels for a parapet.

The outside face of the walls may be shingles, siding, stucco, or brick veneer. The inside face may be either painted or papered.

2. COMPRESSIVE LOAD

Wall specimen *CU–C1* under compressive load is shown in figure 6. The results for wall specimens *CU–C1*, *C2*, and *C3* are given in table 5 and in figures 7 and 8. The lateral deflections shown in figure 8 are plotted to the right of the vertical axis for deflections of the specimens toward the outside face and to the left for deflections toward the inside face.

TABLE 5.—*Structural properties of wall CU*

[Weight, based on the face area: 6.81 lb/ft²]

Compressive load [a]		Transverse load; span 7 ft 6 in.		Impact load; span 7 ft 6 in.		Concentrated load		Racking load	
Specimen	Maximum load	Specimen	Maximum load	Specimen	Maximum height of drop	Specimen	Maximum load	Specimen	Maximum load
	Kips/ft [b]		*lb/ft²*		*ft*		*lb*		*Kips/ft* [b]
C1	11.26	*T1*	368	*I1*	[c] 10.0	*P1*	[c] 1,000	*R1*	2.18
C2	12.48	*T2*	339	*I2*	[c] 10.0	*P2*	[c] 1,000	*R2*	2.06
C3	11.51	*T3*	357	*I3*	[c] 10.0	*P3*	[c] 1,000	*R3*	2.17
Average	11.75	Average	355	Average	[c] 10.0	Average	[c] 1,000	Average	2.14
		T4	288	*I4*	[c] 10.0	*P4*	889		
		T5	270	*I5*	[c] 10.0	*P5*	793		
		T6	291	*I6*	[c] 10.0	*P6*	820		
		Average	283	Average	[c] 10.0	Average	834		

[a] The compressive loads were applied one-third the thickness of the structural portion (1.33 in.) from the inside face.
[b] A kip is 1,000 lb.
[c] Specimen did not fail. Test discontinued.

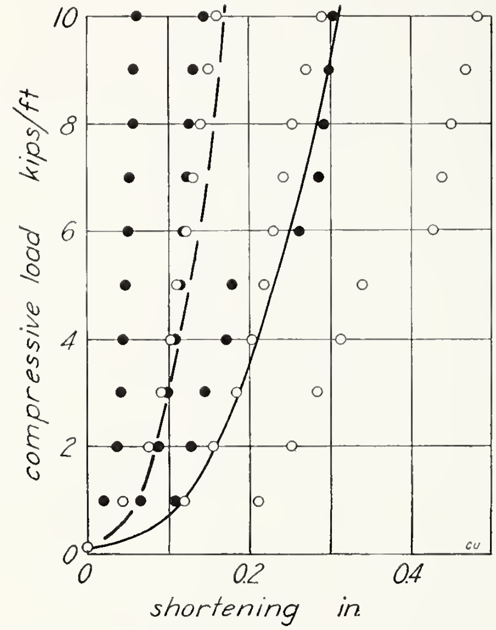


FIGURE 7.—*Compressive load on wall CU.*

Load-shortening (open circles) and load-set (solid circles) results for specimens *CU-C1, C2,* and *C3*. The load was applied 1.33 in. (one-third the thickness of structural portion of the wall) from the inside face. The loads are in kips per foot of actual width of specimen.

There were considerable differences in the shortening and in the set of the individual specimens, particularly under low loads. At the bottom and top the insulating board projected beyond the ends of the specimens and the web of some of the wall panels projected beyond the turned-in portion of the flanges as much as 1/32 in. Also, the sill was not in close contact with the end of the panels.

The load was eccentric toward the inside face, and the lateral deflection of specimens *CU-C1* and *C2* was toward the outside face. However, the deflection of *CU-C3* was toward the inside face for loads up to 5 kips/ft, when the bolts which fastened the sill to the panels sheared and allowed the ends of the panels to come into contact with the sill. Under greater loads the deflection was toward the outside face but was somewhat less than the deflection of specimens *CU-C1* and *C2*.

The lateral set of each of the specimens under

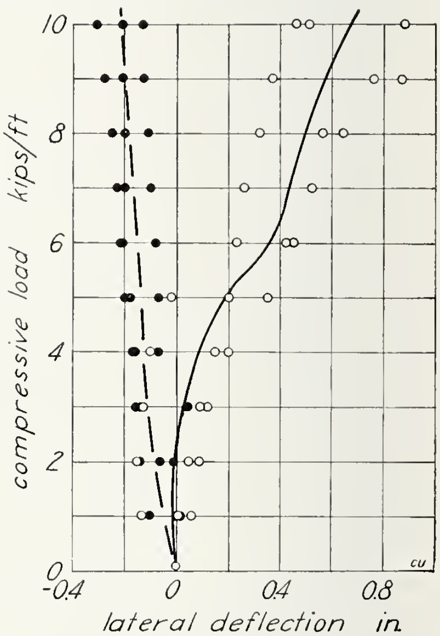


FIGURE 8.—*Compressive load on wall CU.*

Load-lateral deflection (open circles) and load-lateral set (solid circles) results for specimens *CU-C1, C2,* and *C3*. The load was applied 1.33 in. (one-third the thickness of the structural portion of the wall) from the inside face. The loads are in kips per foot of actual width of specimen. The deflections and sets are for a gage length of 7 ft 6 in., the gage length of the deflectometer.

most loads was toward the inside face. No explanation of the negative lateral sets was found.

The web (inside face) of one full-width panel began to buckle locally about 2 ft from the top of specimen *CU–C1* under a load of 4.5 kips/ft and under a load of 7.0 kips/ft on specimens *C2* and *C3*. Under a load of 7.5 kips/ft, the web of each panel buckled near the top in specimen *C1*; and under a load of 8.0 kips/ft, on specimen *C2*. One stud buckled near the bottom of specimen *C3* under a load of 9.0 kips/ft. Under greater loads this buckling increased until the maximum load was reached.

3. Transverse Load

The results of the transverse loads are shown in table 5 and in figure 9 for wall specimens *CU–T1*, *T2*, and *T3*, loaded on the inside face,

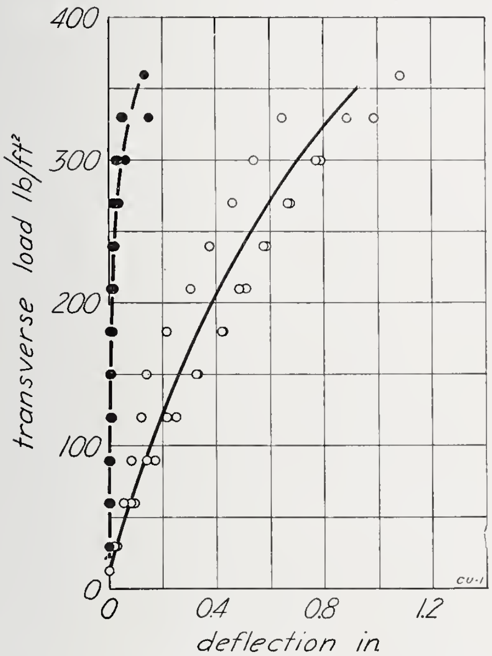


Figure 9.—*Transverse load on wall CU, load applied to inside face.*

Load-deflection (open circles) and load-set (solid-circles) results for specimens *CU–T1*, *T2*, and *T3* on the span 7 ft 6 in.

and in figure 10 for wall specimens *T4*, *T5*, and *T6*, loaded on the outside face.

Under the maximum load applied to the inside face (web of panels), specimens *CU–T1*, *T2*, and *T3* failed by buckling of two or more studs between the loading rollers.

Specimens *CU–T4*, *T5*, and *T6* were loaded on the outside face (siding). The flanges buckled where they were pierced by the nails fastening the insulating board and the siding. Under a load of 240 lb/ft² on specimens *T4* and *T5*, the buckling of the flanges increased under

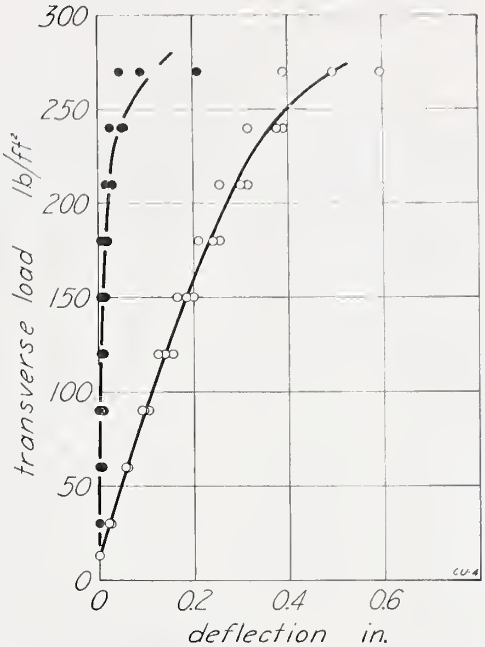


Figure 10.—*Transverse load on wall CU, load applied to outside face.*

Load-deflection (open circles) and load-set (solid circles) results for specimens *CU–T4*, *T5*, and *T6* on the span 7 ft 6 in.

the loading rollers. Under the maximum load, each specimen failed by buckling of the studs under the loading rollers.

4. Impact Load

The results of the impact loads are shown in table 5 and in figure 11 for wall specimens *CU–I1*, *I2*, and *I3*, loaded on the inside face, and in figure 12 for specimens *CU–I4*, *I5*, and *I6*, loaded on the outside face.

The impact loads were applied to the center of the inside face of specimens *I1*, *I2*, and *I3*, the sandbag striking the steel sheet directly over the center stud. The center stud was buckled slightly after a drop of 7.0 ft on specimen *CU–I1* and after a drop of 8.0 ft on specimens *I2* and *I3*. There was no failure of either face of specimens *I1* and *I2*. In specimen *I3* after the 10-ft drop, there was a ¼-in.

opening between the inner panels on the face struck and one piece of siding on the opposite face was completely separated from the specimen.

After the 10-ft drop, the sets in specimens *CU–I1*, *I2*, and *I3* were 0.51, 0.62, and 0.69 in., respectively.

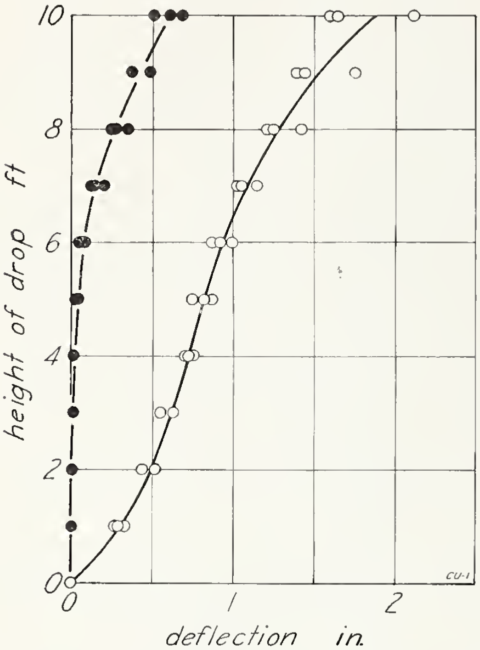


FIGURE 11.—*Impact load on wall CU, load applied to inside face.*

Height of drop-deflection (open circles) and height of drop-set (solid circles) results for specimens *CU–I1*, *I2*, and *I3* on the span 7 ft 6 in.

TABLE 6.—*Effects of impact load on wall specimens CU–I4, I5, and I6, loaded on the outside face*

Description of effects	Specimen *I4* Height of drop	Specimen *I4* Deflection	Specimen *I5* Height of drop	Specimen *I5* Deflection	Specimen *I6* Height of drop	Specimen *I6* Deflection
Face loaded:						
Flange of center stud buckled where the sandbag struck	*ft* 4.0	*in.* 1.17	*ft* 4.5	*in.* 0.71	*ft* 4.0	*in.* 0.73
Nails through siding pulled from the studs where the sandbag struck	5.5	2.00	5.5	1.41	5.0	1.44
One piece of siding split where the sandbag struck	5.0	1.72	6.5	1.92	6.0	2.08
Failure: Crack in siding extended full width of specimen	6.0	2.17	8.0	2.72	6.5	2.40
Face not loaded: Failure; wall panels separated where sandbag struck	7.0	2.74	8.0	2.72	7.5	3.09

The impact loads were applied to the center of the outside face of specimens *I4*, *I5*, and *I6*, the sandbag striking the bevel siding directly over the center stud. The effects of the impact loads are given in table 6.

After the 10-ft drop the set in specimen *CU–I4* was 1.16 in.; in *I5*, 1.60 in.; and in *I6*, 2.93 in.

5. CONCENTRATED LOAD

The results of the concentrated loads are given in table 5 and in figure 13 for specimens *CU–P1*, *P2*, and *P3*, loaded on the inside face, and in figure 14 for specimens *CU–P4*, *P5*, and *P6*, loaded on the outside face.

The concentrated loads were applied to the inside face (web of panels) of specimens *CU–P1*, *P2*, and *P3* on a full-width panel midway between studs and 2 ft from one end of the specimen. After a load of 1,000 lb had been applied, the sets in specimens *P1*, *P2*, and *P3* were 0.33, 0.14, and 0.19 in., respectively. No other effects were observed.

The concentrated loads were applied to the outside face (siding) of specimens *CU–P4*, *P5*, and *P6* midway between studs, 2 ft 7 in. from one end of the specimen. The siding cracked parallel to the grain under the loading disk at a load of 512 lb on specimen *P4*, 560 lb on *P5*,

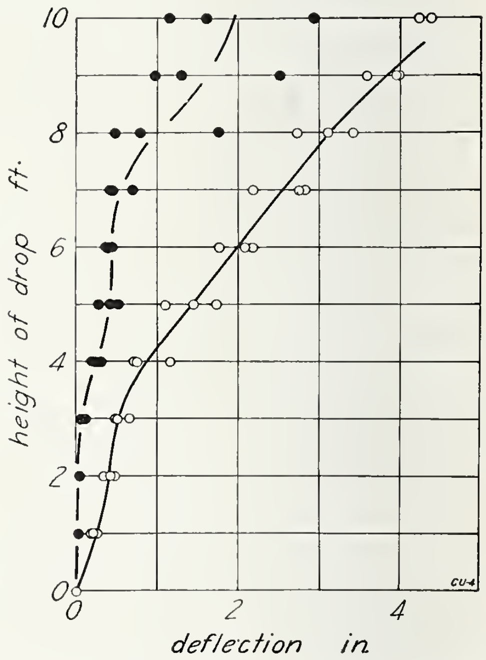


FIGURE 12.—*Impact load on wall CU, load applied to outside face.*

Height of drop-deflection (open circles) and height of drop-set (solid circles) results for specimens *CU–I4*, *I5*, and *I6* on the span 7 ft 6 in.

and 650 lb on *P6*. Under the maximum load on each specimen, the disk punched through the siding and into the insulating board.

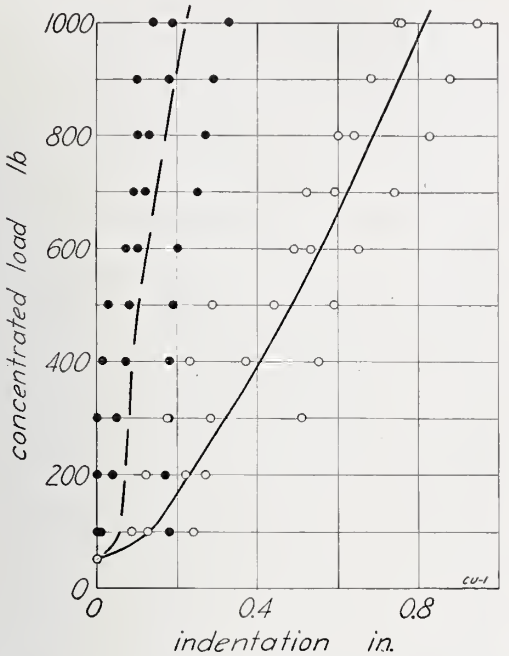


FIGURE 13.—*Concentrated load on wall CU, load applied to inside face.*

Load-indentation (open circles) and load-set (solid circles) results for specimens *CU-P1*, *P2*, and *P3*.

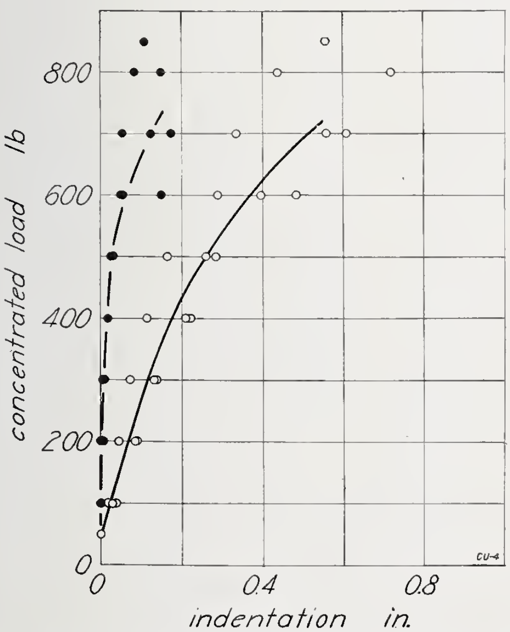


FIGURE 14. *Concentrated load on wall CU, load applied to outside face.*

Load-indentation (open circles) and load-set (solid circles) results for specimens *CU-P4*, *P5*, and *P6*.

6. Racking Load

Wall specimen *CU-R1* under racking load is shown in figure 15. The results for wall specimens *CU-R1*, *R2*, and *R3* are shown in table 5 and figure 16.

The racking loads were distributed along the top of the specimen by a structural-steel channel bolted to a steel plate which was in turn bolted to the angle cap. The sill angle was also

FIGURE 15.—*Wall specimen CU-R1 under racking load.*

A, deformeter.

bolted to a structural-steel channel which was in contact with the stop.

At a load of 2.0 kips/ft the wall panels in specimens *R2* and *R3* began to buckle. The maximum load sheared the bolts fastening the sill in specimens *R1* and *R2* and the bolts fastening the angle cap in specimen *R3*.

VI. PARTITION *CV*

1. Sponsor's Statement

Partition *CV* consisted of prefabricated sheet-steel channels joined at the flanges and steel sheets. The face formed by the webs of the channels was designated the "inside" face, which corresponded to the inside face of wall *CU*.

The face formed by the steel sheet fastened to the flanges of the panels was designated the "outside" face. The surface of the steel was covered with paint.

The price of this construction in Washington, D. C., as of July 1937, was $0.35/ft².

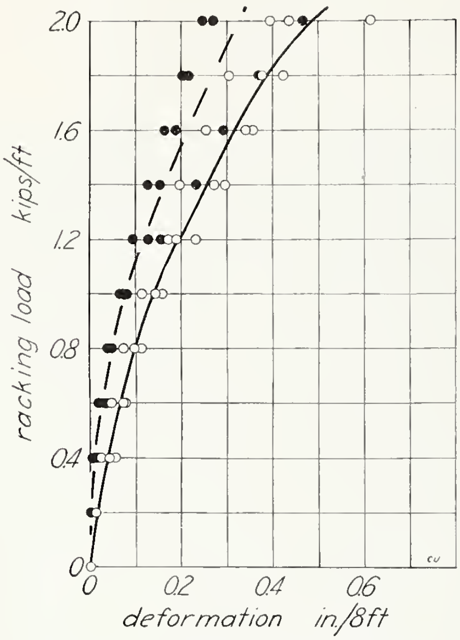


FIGURE 16.—*Racking load on wall CU.*

Load-deformation (open circles) and load-set (solid circles) results for specimens *CU-R1*, *R2*, and *R3*. The loads are in kips per foot of actual width of specimen.

(a) *Description*

The partition specimens, shown in figure 17, were 8 ft ⅜ in. high, 5 ft 0 in. wide, and 4$\frac{1}{16}$ in. thick. Each consisted of two full-width channel-shaped partition panels, *A;* two half-width partition panels, *B;* angle sill, *C;* angle cap, *D;* two steel sheets, *E;* and spacer blocks, *F.*

Partition panels.—The full-width partition panels, *A*, were sheet steel, No. 16 U. S. Std. Gage (0.0613 in. thick), 8 ft ⅛ in. long, 1 ft 8 in. wide, and 4 in. deep. The edges of the flanges were turned in 2 in., as shown in figure 3, for attaching the "outside" face and to increase the strength of the panel. Adjacent panels were fastened through the flanges by stove bolts, ¼-in. diam, ½ in. long. There were two rows of nine bolts each, spaced as shown in figure 4.

The half-width panels, *B*, were the same as a full-width panel cut along a longitudinal center line. In a house there are no half-width panels.

Sill.—The angle sill, *C*, sheet steel, No. 11 U. S. Std. Gage (0.1225 in. thick), was 4⅛ by 2 in. by 5 ft ¼ in. long. The sill was fastened to the panels by 10 stove bolts, ¼-in. diam, ½ in. long, through the vertical (2-in.) leg of the angle and the webs of the panels. The spacing of the bolts is shown in figure 4.

Cap.—The angle cap, *D*, rolled structural steel, was 2 by 2 by ¼ in., 5 ft ¼ in. long. The cap was fastened to the panels by 10 stove bolts, ¼-in. diam, ½ in. long, through the vertical leg of the cap and the webs of the panels. The spacing of the bolts is shown in figure 4.

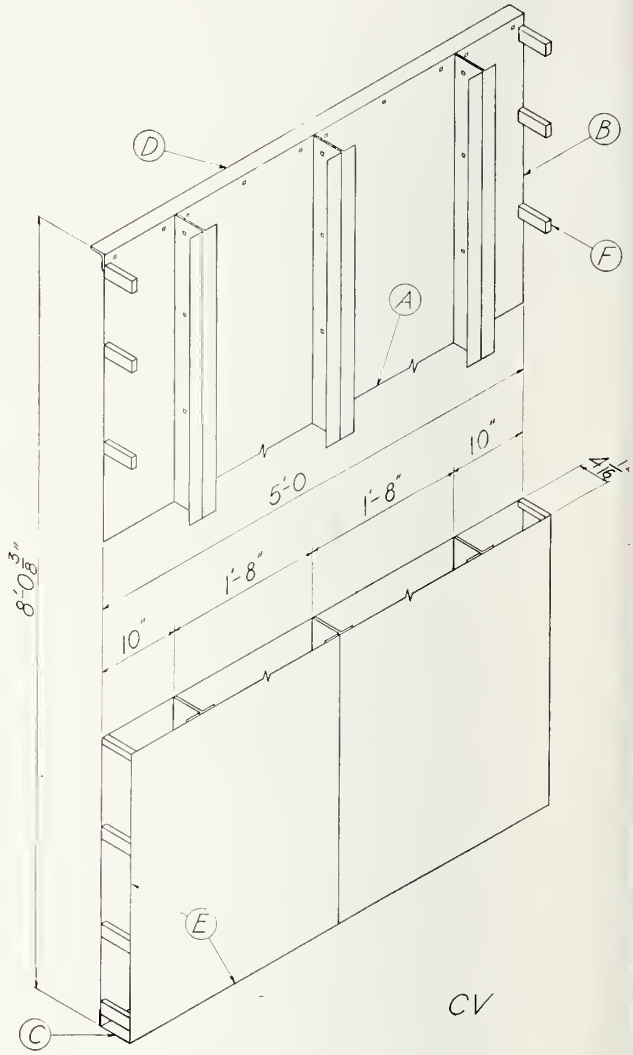


FIGURE 17.—*Partition specimen CV.*

A, full-width partition panels; *B*, half-width partition panels; *C*, angle sill; *D*, angle cap; *E*, steel sheets; *F*, spacer blocks.

Fabrication.—Adjacent panels were clamped together and the bolt holes laid off with a rule

and marked with a center punch. The holes were drilled with a twist drill, ¼-in. diam, mounted in an electric hand drill.

The sills and the cap were then clamped to the wall panels and the bolt holes laid off. The difference between the nominal spacing and the actual spacing of the holes was as much as ¼ in. in some instances.

In a house all the panels are full width and no half-width panels are used. The middle bolt fastening the sill and the cap to the web of a panel is at midwidth of the panel. In the 4-ft partition specimens, therefore, there should have been a bolt of one-half the cross-sectional area at the edge of the specimen fastening the sill and cap to each half-width panel. For convenience the bolts were full-sized (¼-in. diam) and, to provide an effective fastening, 1¼ in. from the edge of the specimen. It is believed that these changes had very little effect upon the structural properties of the specimens.

Sheets.—The steel sheets, *E*, No. 16 U. S. Std. Gage (0.0613 in. thick), were 8 ft 0 in. long and 2 ft 6 in. wide. There was a vertical joint on the center stud. Each sheet was fastened to each stud by a row of 1½-in. screw nails spaced 1 ft. The nails were driven close to the joint between panels to minimize bending of the flanges. In some instances the flanges were bent inward ¹⁄₁₆ in.

Paint.—After the panels, sill, and cap were assembled, the exposed surface was covered with one coat of aluminum paint applied with a brush. Both sides of the steel sheets were covered with one coat of aluminum paint before fastening to the wall panels.

Blocks.—The spacer blocks, *F*, were cypress, ¾ by 1⅝ in., 4 in. long, spaced 1 ft, nine blocks along each edge of the specimen. Each block was fastened to the half-width panel and to the steel sheet by one 1½-in. screw nail through the steel and into the block. In a house there are no spacer blocks.

(*b*) *Comments*

The panels, sill, and cap of the partition specimens were like those in wall *CU*.

In a house the edge flange of the partition is bolted to the web of the wall panels at the intersection of a partition and an outside wall.

2. Impact Load

The results of the impact tests are shown in table 7 and figure 18 for partition specimens *CV–I1*, *I2*, and *I3*, loaded on the "inside" face; in figure 19 for specimens *CV–I4*, *I5*, and *I6*, loaded on the "outside" face.

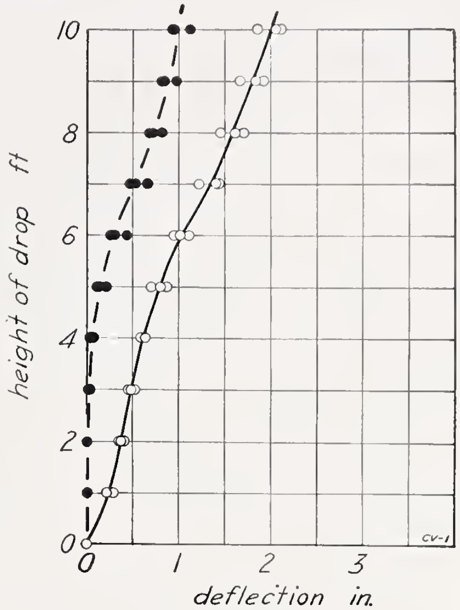


Figure 18.—*Impact load on partition CV, load applied to "inside" face.*

Height of drop-deflection (open circles) and height of drop-set (solid circles) results for specimens *CV–I1*, *I2*, and *I3* on the span 7 ft 6 in.

Table 7.—*Structural properties of partition CV*

[Weight, based on face area: 7.08 lb/ft²]

Impact load; span 7 ft 6 in.		Concentrated load	
Specimen	Maximum height of drop	Specimen	Maximum load
	ft		*lb*
I1	[a] 10.0	*P1*	[b] 1,000
I2	[a] 10.0	*P2*	[b] 1,000
I3	[a] 10.0	*P3*	[b] 1,000
Average	[a] 10.0	Average	[b] 1,000
I4	[a] 10.0	*P4*	[a] 1,000
I5	[a] 10.0	*P5*	[a] 1,000
I6	[a] 10.0	*P6*	[a] 1,000
Average	[a] 10.0	Average	[a] 1,000

[a] Test discontinued; specimen damaged.
[b] Test discontinued; specimen undamaged.

The impact loads were applied to the center of the "inside" face of specimens *I1*, *I2*, and *I3*, the sandbag striking the web of the panels directly over the center stud. The effects are given in table 8.

Table 8.—*Effects of impact load on partition specimens CV–I1, I2, and I3, loaded on the "inside" face*

Description of effects	Specimen I1		Specimen I2		Specimen I3	
	Height of drop	Deflection	Height of drop	Deflection	Height of drop	Deflection
Face loaded:						
Local buckling of steel where the sandbag struck	*ft* 6.0	*in.* 1.01	*ft* 4.5	*in.* 0.70	*ft* 6.5	*in.* 1.10
Flanges of panels began to separate along center stud	5.0	0.80	6.0	1.11		
Face not loaded:						
Steel sheet began to separate; the nails pulled from flanges of wall panels	3.5	.62	3.5	0.54	5.5	0.95
A few nails dropped from specimen	6.5	1.40	5.0	.87	7.0	1.22

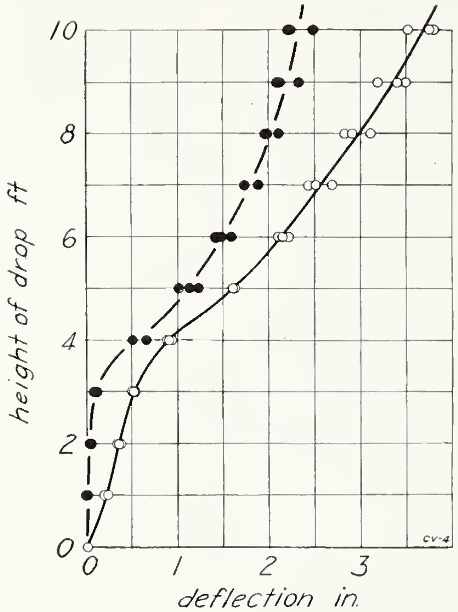


Figure 19.—*Impact load on partition CV, load applied to "outside" face.*

Height of drop-deflection (open circles) and height of drop-set (solid circles) results for specimens *CV–I4, I5,* and *I6* on the span 7 ft 6 in.

After the 10-ft drop the set in specimen *CV–I1* was 0.95 in.; in *I2*, 1.13 in.; and in *I3*, 0.94 in.; and the flanges had separated ½ in. where the sandbag struck.

The impact loads were applied to the center of the "outside" face of specimens *I4*, *I5*, and *I6*, the sandbag striking the steel sheet directly over the center stud. The effects are given in table 9.

After the 10-ft drop the set in specimen *CV–I4* was 2.21 in.; in *I5*, 2.24 in.; and in *I6*, 2.50 in.

Table 9.—*Effects of impact load on partition specimens CV–I4, I5, and I6, loaded on the "outside" face*

Description of effects	Specimen I4		Specimen I5		Specimen I6	
	Height of drop	Deflection	Height of drop	Deflection	Height of drop	Deflection
Face loaded:						
Steel sheets buckled where sandbag struck	*ft* 4.0	*in.* 0.94	*ft* 4.0	*in.* 0.89	*ft* 4.0	*in.* 0.91
Nails in one or more studs began to pull from flanges of the panels	2.5	.47	7.5	2.90	8.5	3.01
Flanges of the panels began to separate along center stud	4.0	.94	4.0	0.89	5.0	1.63
Steel sheets buckled adjacent to center stud at top and bottom of specimen			6.5	2.44	6.0	2.10
Flanges of panels buckled where sandbag struck	10.0	3.75	10.0	3.80	10.0	3.52
Face not loaded: Flanges of panels separated ¼ in. where sandbag struck	8.0	2.91	6.5	2.44	6.5	

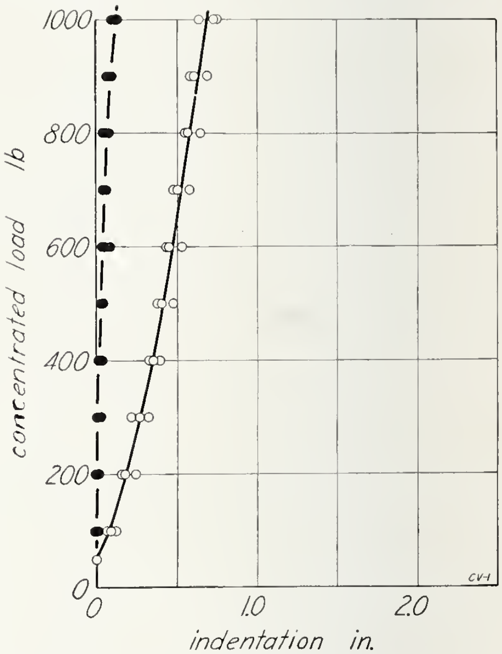


Figure 20.—*Concentrated load on partition CV, load applied to "inside" face.*

Load-indentation (open circles) and load-set (solid circles) results for specimens *CV–P1, P2,* and *P3*.

3. Concentrated Load

Partition specimen *CV–P5* under concentrated load is shown in figure 1. The results for partition specimens *CV–P1*, *P2*, and *P3*, loaded on the "inside" face, are shown in table 7 and figure 20. The results for partition specimens *CV–P4*, *P5*, and *P6*, loaded on the "outside" face, are shown in table 7 and figure 21.

The concentrated loads were applied to the "inside" face of specimens *CV–P1*, *P2*, and *P3* on the web of a wall panel midway between the studs and 20 in. from the bottom of the specimen. After a load of 1,000 lb had been applied, the set in specimen *CV–P1* was 0.125 in.; in *P2*, 0.128 in.; and in *P3*, 0.095 in. No other effects were observed.

The concentrated loads were applied to the "outside" of specimens *CV–P4*, *P5*, and *P6* on the steel sheet midway between the studs and 20 in. from the bottom of the specimen. Under a load of 1,000 lb the steel sheet for each specimen deflected 3.5 in., to within 0.5 in. of the opposite face, and the flanges of the panels separated adjacent to the disk. After the 1,000-lb load had been removed, the set in specimen *P4* was 0.87 in.; in *P5*, 1.21 in.; and *P6*, 1.01 in.

VII. FLOOR *CW*

1. Sponsor's Statement

Floor *CW* consisted of prefabricated sheet-steel channels joined at the flanges; the webs were the lower face. The upper face was a wood subfloor and a wood finish floor. The surface of the channels was covered with paint.

The price of this construction in Washington, D. C., as of July 1937, was $0.44/ft².

(*a*) *Description*

Each floor specimen, shown in figure 22, was 12 ft 6 in. long, 5 ft 0 in. wide, and 9⁹⁄₁₆ in. deep and consisted of two full-width channel-shaped floor panels, *A;* two half-width floor panels, *B;* subflooring, *C;* spacer blocks, *D;* and finish flooring, *E.*

Floor panels.—The full-width floor panels, *A*, sheet-steel, No. 16 U. S. Std. Gage (0.0613 in. thick), were 12 ft 6 in. long, 1 ft 8 in. wide, and 8 in. deep. The edges of the flanges were turned in 2 in., as shown in figure 23, for attaching the subfloor and to increase the strength of the panel. Adjacent panels were fastened through the flanges by stove bolts, ¼-in. diam, ½ in. long. There were two rows of 14 bolts each, spaced as shown in figure 24.

The half-width floor panels, *B*, were the same as a full-width panel cut along a longitudinal center line. In a house there are no half-width panels.

Fabrication.—Adjacent panels were clamped together, and the bolt holes were laid off with a rule and marked with a center punch. The holes were drilled with a twist drill, ¼-in. diam, mounted in an electric hand drill.

Paint.—Before assembling, the flange of each floor panel was covered with one coat of aluminum paint applied with a brush to the surface which would come into contact with the adjacent panel. After the panels were assembled, they were covered with two coats of aluminum paint applied with a brush.

Subfloor.—The subflooring, *C*, was southern yellow pine, ²⁵⁄₃₂ in. thick by 5¼ in. face width,

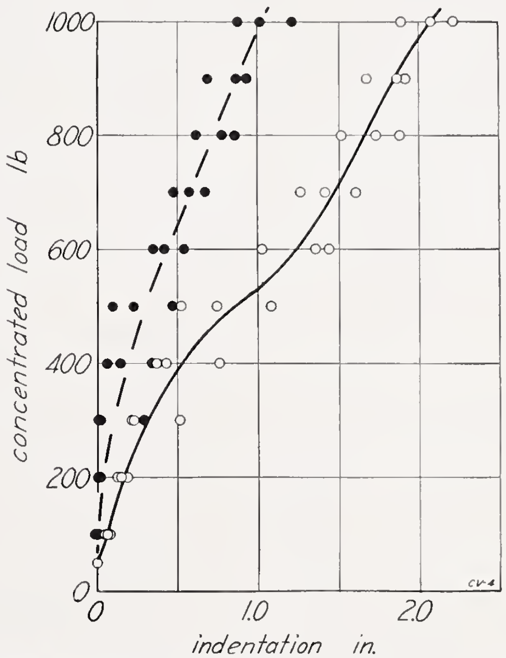


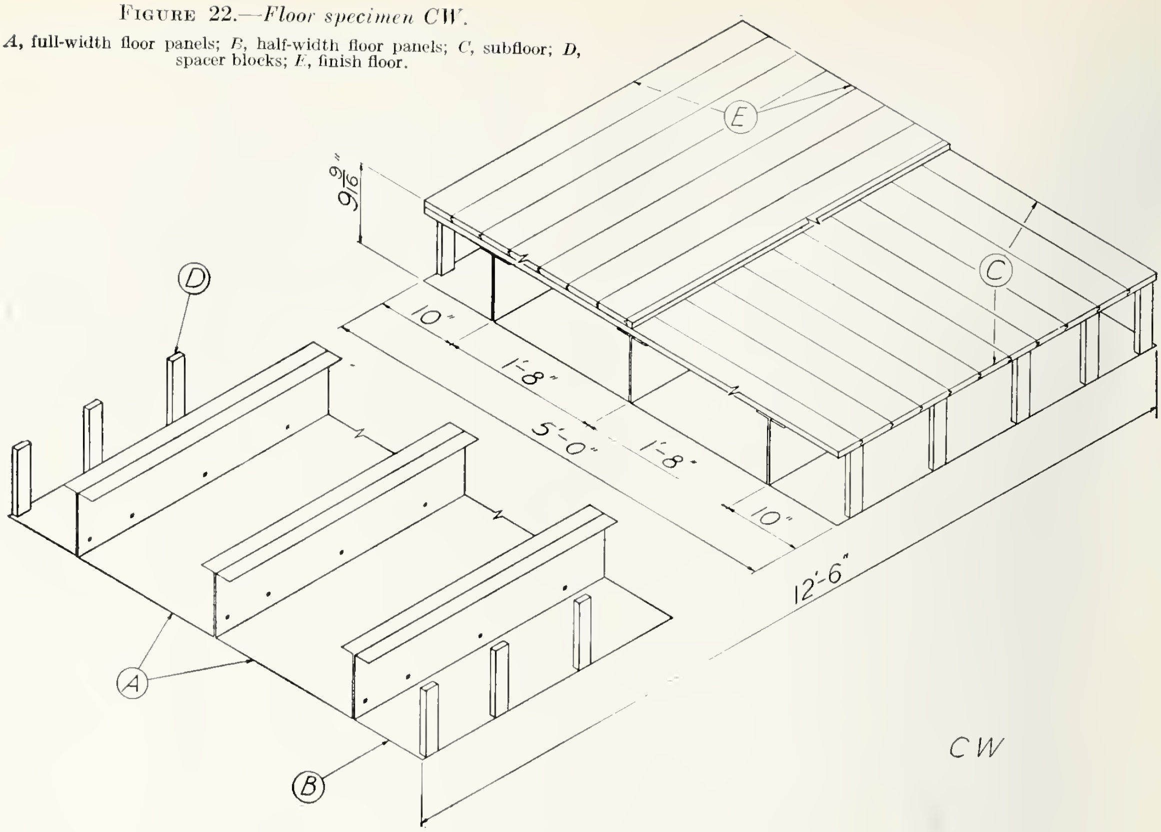
Figure 21.—*Concentrated load on partition CV, load applied to "outside" face.*

Load-indentation (open circles) and load-set (solid circles) results for specimens *CV–P4*, *P5*, and *P6*.

tongued and grooved, and was laid at right angles to the panels. Each piece was fastened to each joist by one 1¾-in. screw nail, driven through the wood and the flange. (A "joist" is the two flanges of adjacent channels.) The nails in adjacent boards were through alternate flanges of the center joist and in the outside flanges of the outer joists. The nails were close to the joint between panels to minimize bending

Figure 22.—*Floor specimen CW.*

A, full-width floor panels; *B*, half-width floor panels; *C*, subfloor; *D*, spacer blocks; *E*, finish floor.



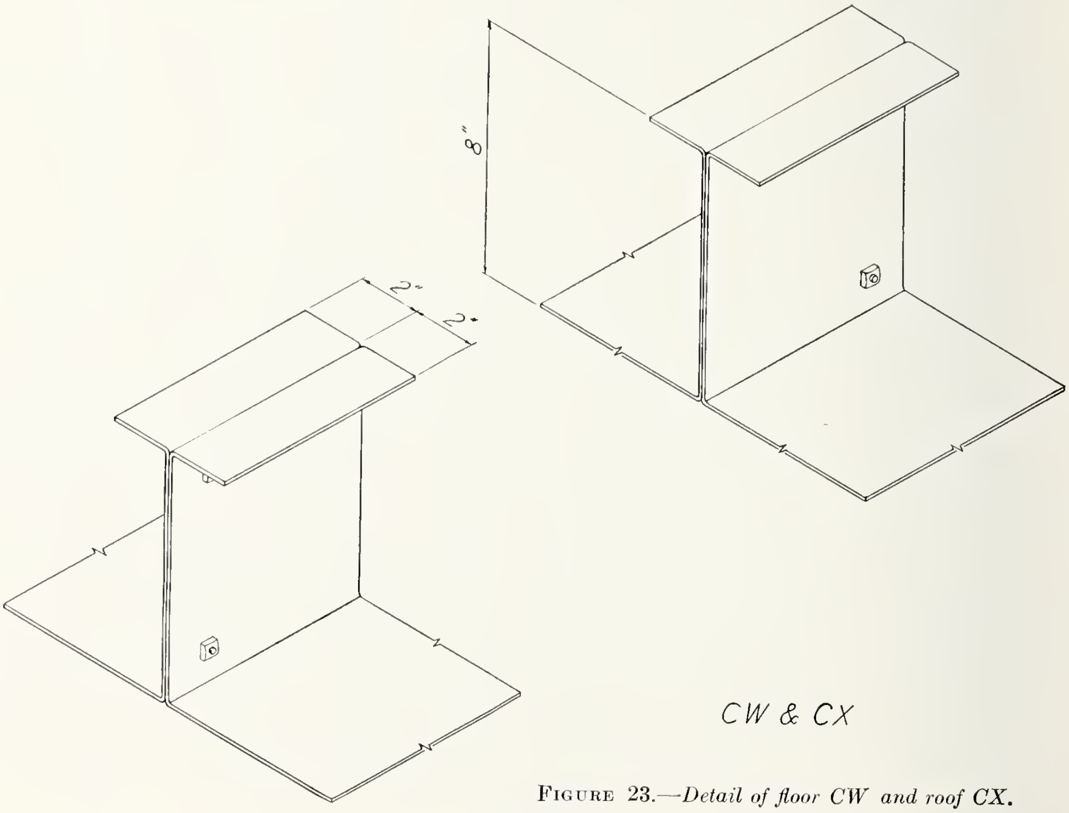


Figure 23.—*Detail of floor CW and roof CX.*

of the flanges. A few nails were between the flanges.

Blocks.—The spacer blocks, *D*, were cypress, ¾ by 1⅝ by 8 in. long, 13 along each edge of the specimen, spaced 1 ft. Each block was fastened to the half-width panel by one 1¾-in. screw nail through the steel and into the block and to the subfloor by one 1¾-in. screw nail through the subfloor and into the block. In a house there are no spacer blocks.

Finish floor.—The finish floor, *E*, like the subfloor, was southern yellow pine, 25/32 in. thick by 5¼ in. face width, tongued and grooved. It was laid parallel to the panels. Each piece was blind-fastened to the subfloor through the grooved edge (not through the tongued edge as is customary) by screw nails, 2½ in. long, spaced 1 ft. 8 in. Most of the nails in the pieces of finish floor over the joists bent and passed between the flange of the joist and the subfloor.

(*b*) *Comments*

Standard floor panels, 1 ft. 8 in. wide and 8 in. deep, are available in lengths up to 20 ft. To expedite the erection of the building, the holes for the bolts in the panels may be punched before the panels are shipped to the site.

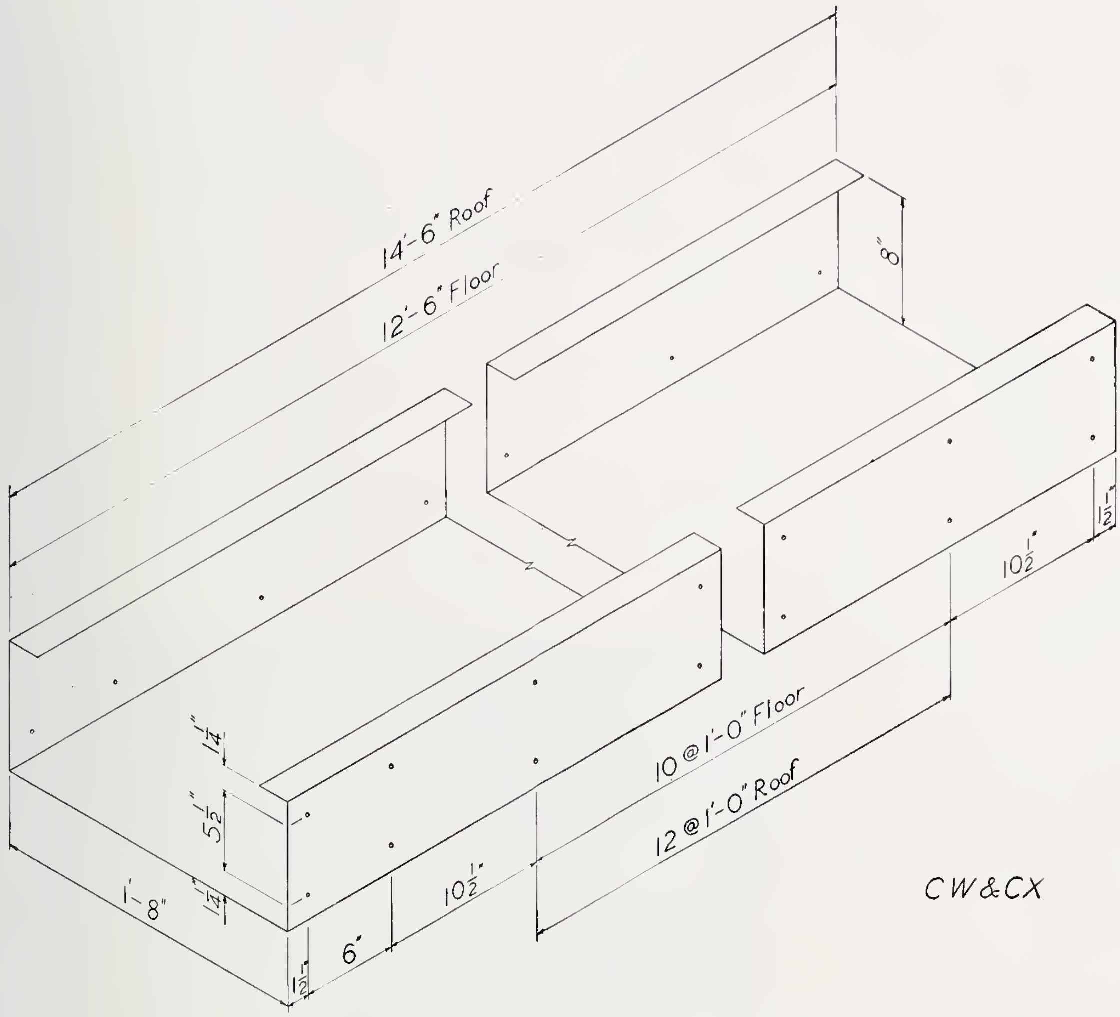


FIGURE 24.—*Bolt spacing for floor and roof panels.*

In a building the first-story floor panels are supported on a masonry wall and a center girder. The top of the masonry wall is covered with asphalt mastic; then a strip of felt impregnated with asphalt is laid on the wall and

coated with asphalt mastic before the panels are placed. The panels are anchored to the wall by bolts, ½-in. diam, 4 in. long, spaced 4 ft.

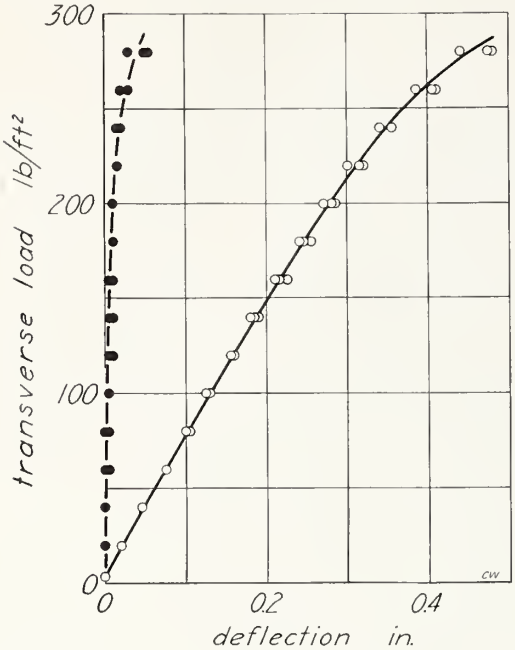


FIGURE 25.—*Transverse load on floor CW.*

Load-deflection (open circles) and load-set (solid circles) results for specimens *CW–T1*, *T2*, and *T3* on the span 12 ft 0 in.

Any type of wood flooring may be applied to the flanges of the floor panels, or a concrete slab may be poured on paper-backed floor lath fastened to the flanges by steel clips. The lower face of the panels (ceiling of the room below) may be painted or papered.

2. Transverse Load

The results for floor specimens *CW–T1*, *T2*, and *T3* under transverse load are shown in table 10 and figure 25.

Under the maximum load, the flanges of each joist in specimen *CW–T1* buckled under a loading roller; in specimen *T2* the two outside joists buckled under a loading roller and the center joist buckled near a support; and in specimen *T3* the center joist buckled under a loading roller and one outside joist buckled between the loading rollers. The subfloor and the finish floor were undamaged.

TABLE 10.—*Structural properties of floor CW*

[Weight, based on face area: 9.16 lb/ft²]

Transverse load; span 12 ft 0 in.		Impact load; span 12 ft 0 in.		Concentrated load	
Specimen	Maximum load	Specimen	Maximum height of drop	Specimen	Maximum load
	lb/ft²		*ft*		*lb*
T1	290	*I1*	[a] 10.0	*P1*	[a] 1,000
T2	286	*I2*	[a] 10.0	*P2*	[a] 1,000
T3	280	*I3*	[a] 10.0	*P3*	[a] 1,000
Average	285	Average	[a] 10.0	Average	[a] 1,000

[a] Specimen did not fail. Test discontinued.

3. Impact Load

Floor specimen *CW–I1* during the impact test is shown in figure 26. The results for floor specimens *CW–I1*, *I2*, and *I3* are shown in table 10 and in figure 27.

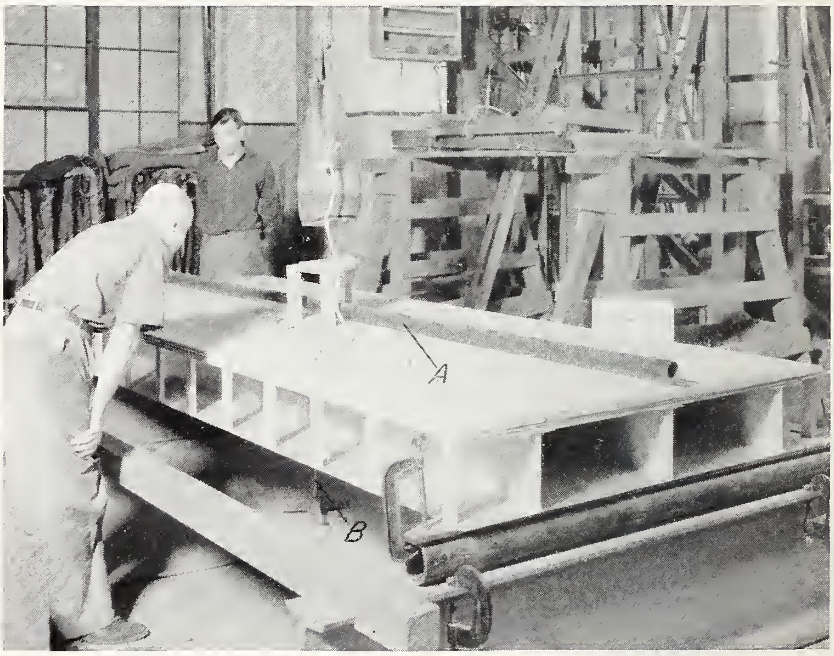


FIGURE 26.—*Floor specimen CW–I1 during the impact test.*

A, set gage; *B*, deflectometer.

The impact loads were applied to the center of the upper face, the sandbag striking the finish floor directly over the center joist. After the 10-ft drop the set in specimen *CW–I1* was 0.061 in.; in *I2*, 0.051.; and in *I3*, 0.021 in. No other effects were observed.

4. Concentrated Load

The results for floor specimens *CW–P1*, *P2*, and *P3* under concentrated load are shown in table 10 and in figure 28.

The concentrated loads were applied to the finish floor midway between joists and 9 in. from one end of the specimen.

After a load of 1,000 lb had been applied, the set in specimen *CW–P1* was 0.043 in.; in *P2*, 0.069 in.; and in *P3*, 0.048 in. No other effects were observed.

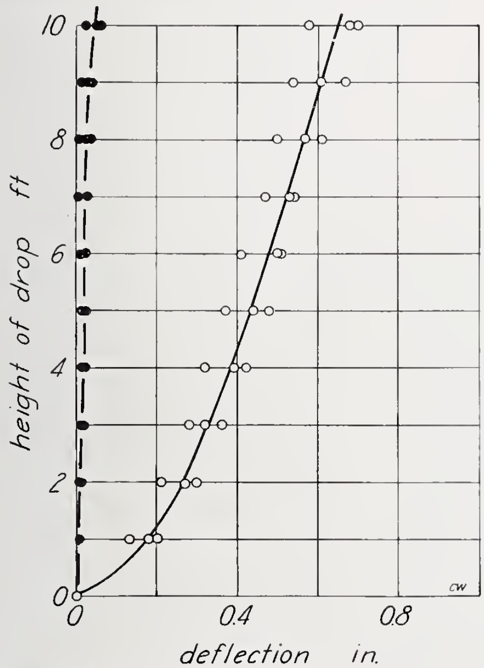


Figure 27.—*Impact load on floor CW.*

Height of drop-deflection (open circles) and height of drop-set (solid circles) results for specimens *CW–I1*, *I2*, and *I3* on the span 12 ft 0 in.

VIII. ROOF *CX*

1. Sponsor's Statement

Roof *CX* consisted of prefabricated sheet-steel channels, joined at the flanges; the webs were the lower face. The upper face was insulating board, wood sheathing, and built-up roofing. The surface of the channels was covered with paint. The channels were similar to those in floor *CW*.

The price of this construction in Washington, D. C., as of July 1937, was \$0.48/ft^2.

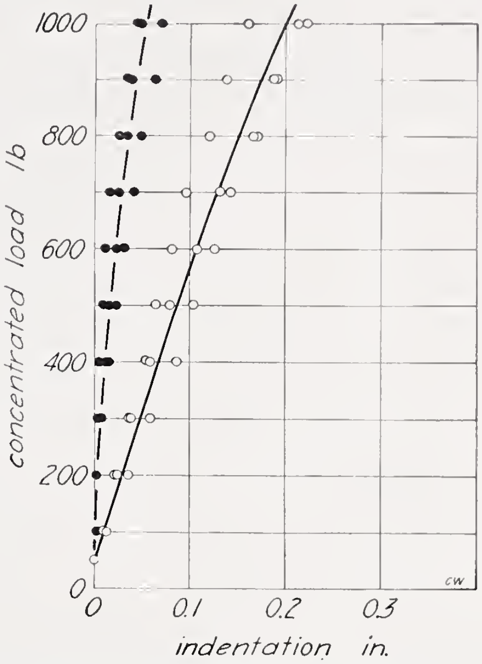


Figure 28.—*Concentrated load on floor CW.*

Load-indentation (open circles) and load-set (solid circles) results for specimens *CW–P1*, *P2*, and *P3*.

(*a*) *Description*

Each roof specimen, shown in figure 29, was 14 ft 6 in. long, 5 ft 0 in. wide, and 9⅜ in. deep. Each specimen consisted of two full-width channel-shaped roof panels, *A*; two half-width roof panels, *B*; insulating board, *C*; wood sheathing, *D*; spacer blocks, *E*; and built-up roofing, *F*.

Roof panels.—The full-width roof panels, *A*, were sheet steel, No. 16 U. S. Std. Gage (0.0613 in. thick), 14 ft 6 in. long, 1 ft 8 in. wide, and 8 in. deep. The edges of the flanges were turned in 2 in., as shown in figure 23, for attaching the wood sheathing and to increase the strength of the panel. Adjacent panels were fastened through the flanges by stove bolts, ¼-in. diam, ½ in. long. There were two rows of 16 bolts each, spaced as shown in figure 24.

The half-width panels, *B*, were the same as a full-width panel cut along a longitudinal center line. In a house there are no half-width panels.

Fabrication.—Adjacent panels were clamped together and the bolt holes laid off with a rule and marked with a center punch. The holes were drilled with a twist drill, ¼-in. diam, mounted in an electric hand drill.

Paint.—Before assembling, the flanges of each panel were covered with one coat of aluminum paint applied with a brush to the surfaces which would come into contact with the adjacent panels. After assembling, the panels were covered with two coats of aluminum paint applied with a brush.

Insulating board.—The insulating board, *C*, ½ in. thick, 5 ft 0 in. wide, was four pieces, three 4 ft 0 in. long and one 2 ft 6 in. long, laid with the "burlap texture" surface up. The piece 2 ft 6 in. long was at one end of the specimen. The insulating board was held in place by the wood sheathing.

Sheathing paper.—There were three strips of sheathing paper each 5 in. wide and 5 ft 0 in. long. A strip was laid over each joint between the insulating boards. They were held in place by the wood sheathing.

Sheathing.—The wood sheathing, *D*, was southern yellow pine, ²⁵⁄₃₂ in. thick and 5¼ in. face width, tongued and grooved, laid over the insulating board at right angles to the joists. Each piece was fastened at midwidth of the strip to each joist by one 1¾-in. screw nail. Nails in successive boards were on alternate sides of the joints between panels and close to the joint to minimize bending of the flanges. A few nails were between the flanges.

Blocks.—The spacer blocks, *E*, were cypress, ¾ by 1⅝ in. by 8 in. long, spaced 1 ft, with 16 along each edge of the specimen. Each block was fastened to the half-width panel by one screw nail, 1¾ in. long, through the web and into the block and to the upper face by a screw nail, 1¾ in. long, through the wood sheathing,

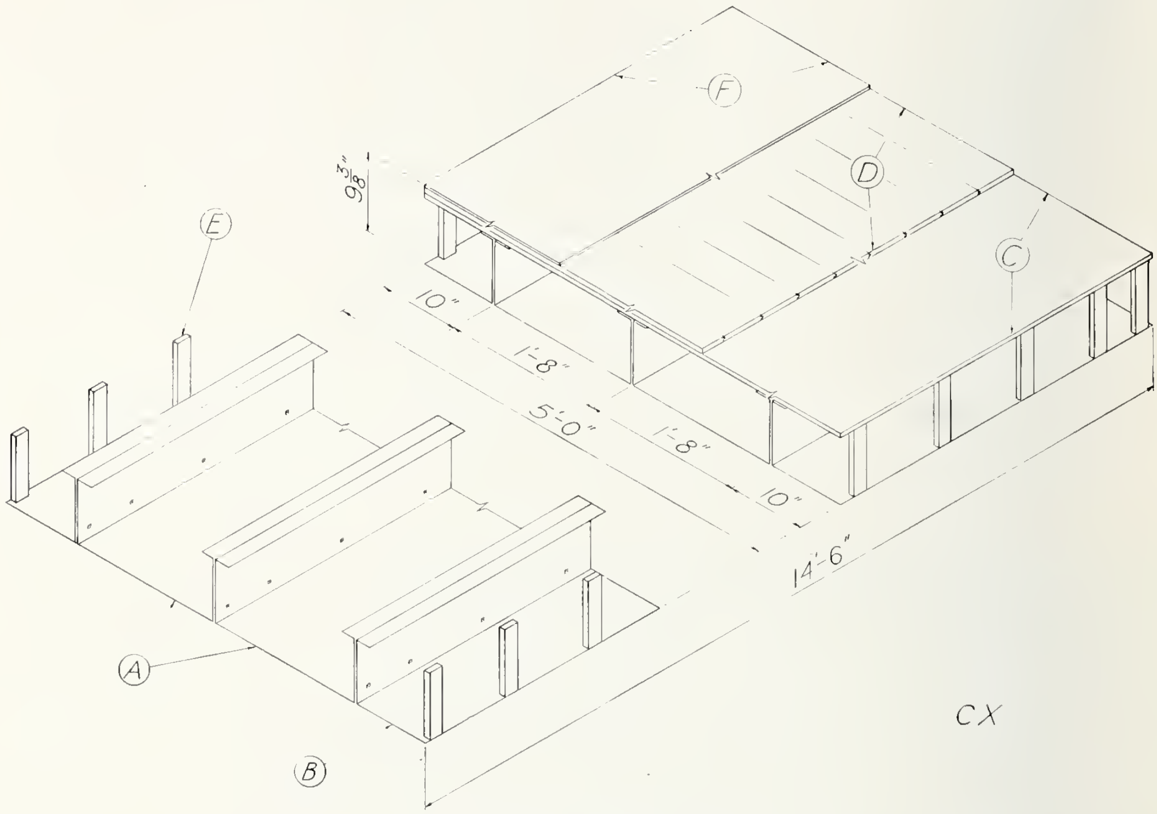


FIGURE 29.—*Roof specimen CX.*

A, full-width roof panels; *B*, half-width roof panels; *C*, insulating board; *D*, wood sheathing; *E*, spacer blocks; *F*, built-up roofing.

the insulating board, and into the block. In a house there are no spacer blocks.

Built-up roofing.—The built-up roofing, *F*, laid over the wood sheathing was two plies of roofing felt and one ply of roofing. Each ply consisted of two strips 3 ft 0 in. wide and 14 ft 6 in. long. The strips overlapped 1 ft 0 in. at midwidth of the specimen. When the built-up roofing was laid, the wood sheathing was covered with roof-coating at room temperature and floated to a uniform thickness. Two strips of 12-lb roofing felt were laid with roof-coating between the overlapping edges. The exposed edge was fastened by roofing nails, 1 in. long, spaced 4¼ in. Roof-coating was then applied. The second ply, consisting of two strips of 12-lb felt, was laid, fastened in the same way as the first, and roof-coating again applied. The third ply, consisting of two strips of 55-lb roll roofing, was laid and fastened in the same way as the first and second plies. Finally, the third ply was covered with roof-coating.

(*b*) *Comments*

The roof may be either the flat or the gable type. If the roof is flat, the roof panels are bolted to the angle cap by stove bolts, ¼-in. diam, ½ in. long, spaced 8¼ in. Wall panels placed horizontally and bolted to the roof panels on three sides of the building form a parapet. The fourth side is left open for run off and is fitted with a galvanized sheet-steel gutter. The sheathing is fastened to tapered wood sleepers, which have a slope of ¼ in. per foot toward the gutter and are fastened longitudinally to the flanges of the panels by screw nails. A built-up roof is applied over the wood sheathing and is extended up the inside of the parapet wall; it is overlapped by a metal or wood cap. For fireproof construction, the cap is an ornamental steel channel, formed of No. 16 U. S. Std. Gage sheet steel, the flanges extending downward over the roofing and the exterior finish. A wood cap is formed by a 2- by 10-in. piece laid flat on the top of the parapet and extending beyond the roofing and the exterior finish. It is nailed to a line of 2- by 4-in. wood pieces bolted to the upper flange of the panel.

If the building has a gable roof, wall panels are used for the roof and ceiling of the upper story. A wood floor laid on the ceiling panels provides an attic floor. At the ridge, the roof panels are connected by two angles formed of No. 16 U. S. Std. Gage sheet steel. The upper one is bolted to the flanges and the lower one to the webs of the panels. At the eaves the roof panels are joined to the ceiling panels by a Z-shaped section formed from No. 16 U. S. Std. Gage sheet steel. The wood sheathing is fastened to the flanges by screw nails, and any suitable roof covering may be applied.

2. Transverse Load

Roof specimen *CX–T2* under transverse load is shown in figure 30. The results for roof specimens *CX–T1*, *T2*, and *T3* are shown in table 11 and in figure 31.

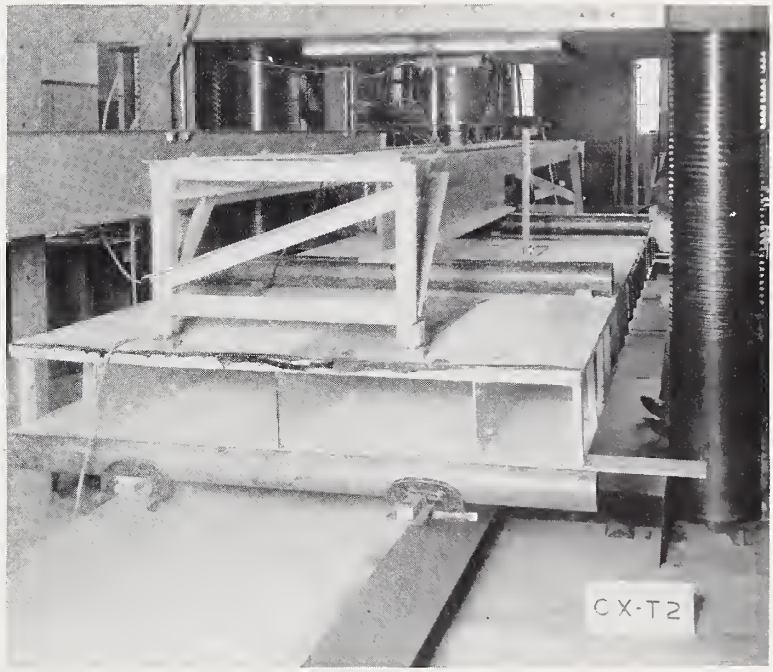


Figure 30.—*Roof specimen CX–T2 under transverse load.*

Table 11.—*Structural properties of roof CX*

[Weight, based on face area: 9.08 lb/ft²]

Transverse load; span 14 ft 0 in.		Concentrated load	
Specimen	Maximum load	Specimen	Maximum load
	lb/ft²		*lb*
T1	183	*P1*	[a] 1,000
T2	180	*P2*	[a] 1,000
T3	180	*P3*	[a] 1,000
Average	181	Average	[a] 1,000

[a] Specimen did not fail. Test discontinued.

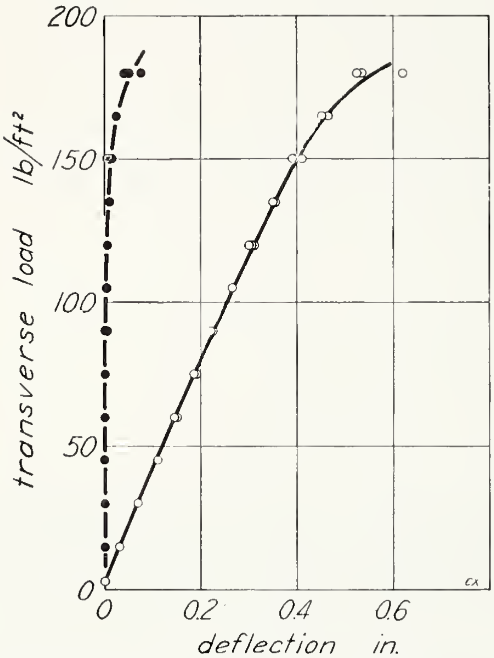


Figure 31.—*Transverse load on roof CX.*

Load-deflection (open circles) and load-set (solid circles) results for specimens *CX–T1*, *T2*, and *T3* on the span 14 ft 0 in.

In specimen *CX–T2* the flanges buckled under the loading rollers at 135 lb/ft². Under the maximum load, the flanges of the center and one outside joist in specimen *CX–T1* buckled between the loading rollers; and in specimens *T2* and *T3* each joist buckled between the loading rollers.

3. Concentrated Load

The results of the concentrated load on roof specimens *CX–P1*, *P2*, and *P3* are given in table 11 and figure 32.

The concentrated loads were applied to the upper face on the built-up roofing midway between joists and 1 ft 8 in. from one end of the specimen.

Under a load of 900 lb on each specimen the disk punched through the upper ply of roofing. After the 1,000-lb load had been applied, the set in specimens *CX–P1* and *P2* was 0.115 in. and in *P3* was 0.258 in.

IX. ADDITIONAL COMMENTS BY SPONSOR

Four commercial buildings and three dwellings using the "Mu-Steel" prefabricated panels have been completed or are under contract.

Houses of this construction are built on a reinforced-concrete slab or on masonry walls, with or without basement.

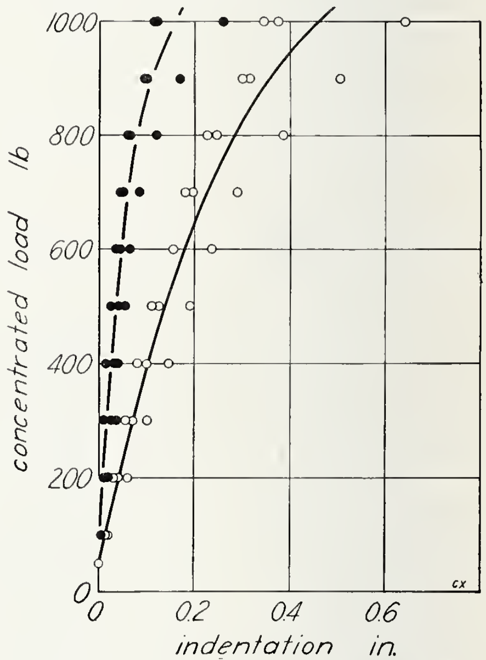


Figure 32.—*Concentrated load on roof CX.*

Load-indentation (open circles) and load-set (solid circles) results for specimens *CX-P1*, *P2*, and *P3*.

For a two-story house the wall panels are continuous from foundation to eaves. The second-story floor rests on and is bolted to an angle cap or shelf bolted to the inside face of the panels. The roof and attic floor, if any, are fastened to a similar angle cap flush with the top of the wall panels. Details of a typical two-story house with a gable roof are shown in figure 33 and of a one-story house with a flat roof in figure 34.

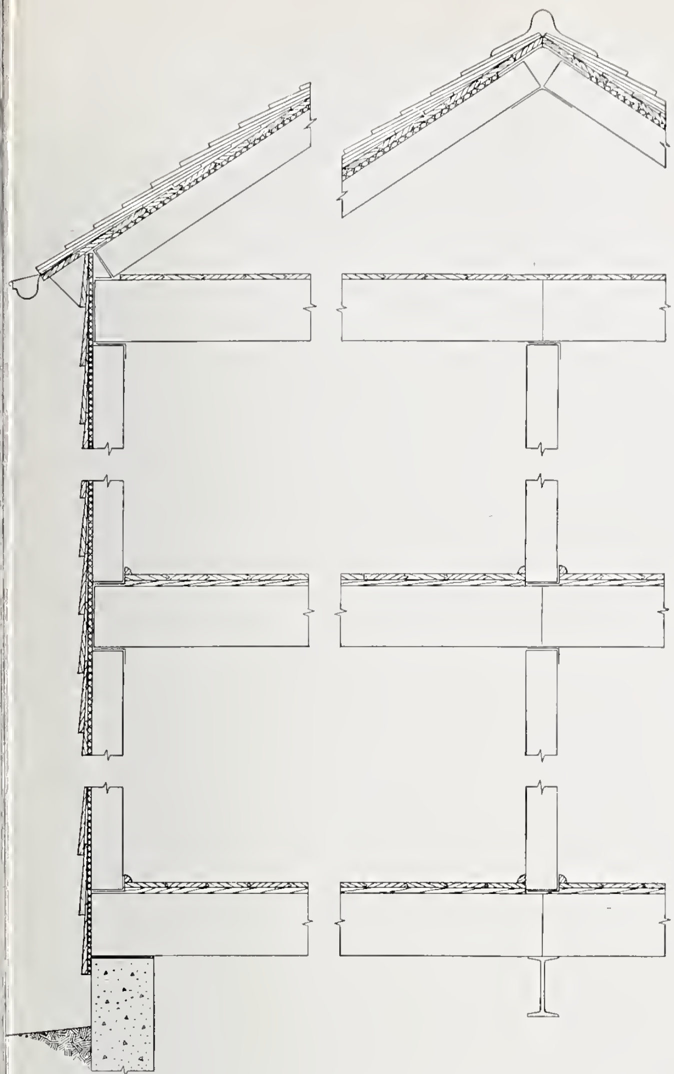


FIGURE 33.—*Details of a two-story house with a gable roof.*

"Mu-Steel" construction.

Pipes, ducts, and conduits are run between the studs and joists. Chimneys are of brick with tile flue linings or of enameled sheet steel suitably insulated.

The physical properties of the insulating board were determined by C. G. Weber and S. G. Weissburg, of the Paper Section, under the supervision of B. W. Scribner.

The description and drawings of the specimens were prepared by E. J. Schell and G. W. Shaw, of the Building Practice and Specifications Section, under the supervision of V. B. Phelan.

The structural properties were determined by the Engineering Mechanics Section, under the supervision of H. L. Whittemore and A. H. Stang, with the assistance of the following members of the professional staff: E. S. Cohen, A. H. Easton, A. Heiter, W. G. Hoback, A. B. Lanham, D. C. List, M. F. Peck, L. R. Sweetman, H. L. Weiss.

WASHINGTON, July 16, 1940.

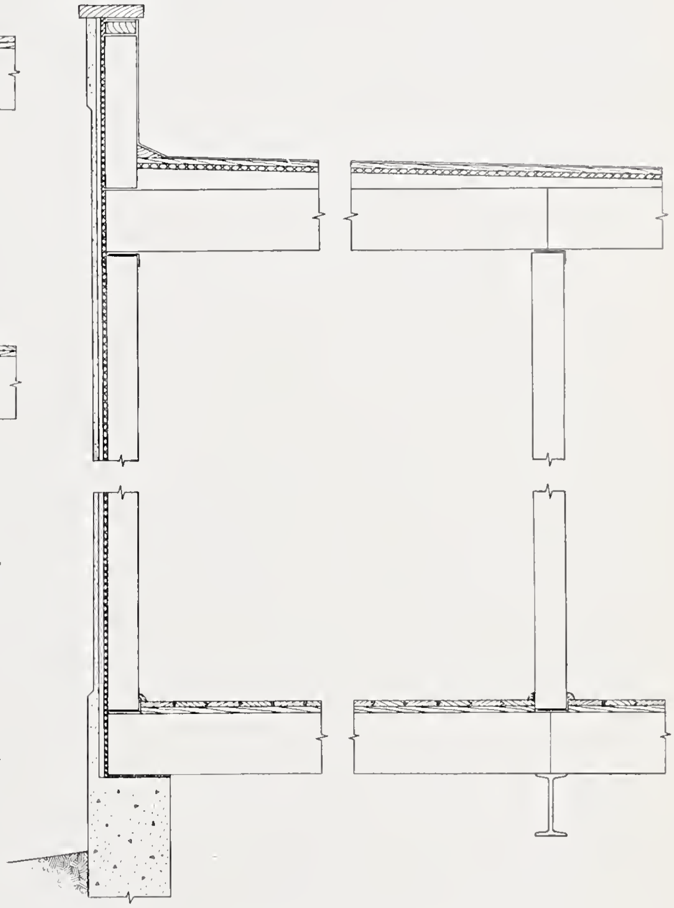


FIGURE 34.—*Details of a one-story house with a flat roof.*

"Mu-Steel" construction.

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[List continued on cover page IV]

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